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A MANUAL

OF

PRACTICAL HYGIENE

FOR

STUDENTS, PHYSICIANS, AND MEDICAL OFFICERS.

BY

CHARLES HARRINGTON, M.D.,

ASSISTANT PROFESSOR OF HYGIENE IN THE MEDICAL SCHOOL OF HARVARD UNIVERSITY.

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AND ONE HUNDRED AND EIGHTEEN ENGRAVINGS.

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PREFACE TO THE THIRD EDITION.

In the preparation of this third edition, matter rendered obsolete by research and study conducted since the appearance of the second edition has been replaced with material in accordance with present knowledge, and other advances have been noted in their appropriate places. In addition, a chapter on the increasingly important subject of Immunity has been introduced, which, it is hoped, may serve a useful purpose.

The author extends hearty thanks to those who have aided him with friendly criticism and suggestions.

C. H.

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PRACTICAL HYGIENE.

CHAPTER I.

FOODS.

Section 1. GENERAL CONSIDERATIONS.

Foods may be said to include everything taken into the system capable of being utilized directly or indirectly to build up normal structure, repair waste, or produce energy in any form, but in the common acceptation of the term they include only those substances which can be oxidized in the system, thus excluding water and air, without which the functions of the body can not be performed. Diet is a mixture of food materials of various kinds habitually taken in such quantity as is needed to maintain or improve the condition of the system.

The Nutritive Value of Foods.

The potential energy of food is measured by the amount of heat which can be obtained by its complete combustion, and is expressed in units of heat or calories. The amount of energy required to raise the temperature of 1 kilogram of water 1° C. is known as a large calorie; that required to raise the temperature of 1 gram to the same extent is known as a small calorie; thus, 1 large calorie equals 1000 small calories. When the term is used without qualification, large calories are understood. These heat units correspond to 425.5 units of work; that is to say, the same amount of energy required to raise the temperature of the given weight of water 1° C. is sufficient to raise 425.5 times the weight one meter. The amount of work done is expressed in kilogram-meters.

The heat unit of the English system is the amount of energy required to raise the temperature of a pound of water 1° F., and its mechanical equivalent is 772 units of work; that is to say, the same amount of energy will raise 772 pounds one foot. According to the English method, work done is expressed in foot tons rather than in foot pounds.

The calorimetric values of different food materials express also their

physiological values as nutriment. Rubner[1] determined the calorimetric value of the proximate principles as follows:

One gram of proteids	= 4.1 calories.
One gram of carbohydrates	= 4.1 "
One gram of fat	= 9.3 "

In the system, the carbohydrates and fats are burned completely to carbonic acid and water, but the proteids leave a residue of urea incapable of still further oxidation. It is estimated that the physiological value of the proteids averages only about 75 per cent. of their calorimetric value.

The calorimetric value of different foods of the several classes is not to be understood as being exactly the same. Thus, two kinds of sugar or two kinds of fat, or two kinds of proteid have not exactly the same calorimetric values, and the figures above given are to be understood only as fair averages. Rubner[2] has determined by actual experimentation the relative calorimetric values of certain food materials, and has shown that 100 grams of fat are equivalent to 225 of syntonin, or 232 of starch, or 234 of cane sugar, or 243 of muscle fiber, or 256 of grape sugar. In other words, these several amounts of food material are isodynamic.

Amount of Food Necessary.

For the maintenance of a proper degree of health and strength, the individual must ingest an amount of food sufficient to meet the daily loss of nitrogen and carbon. This must necessarily vary according to circumstances, and hence no rule can be laid down to fit all cases. The best that can be done is to make certain general rules based on the amount of work performed, for the greater the amount of work done, the greater the amount of food required to meet the necessary consumption of fuel and to repair the tissues. When performing heavy labor, the naturally increased desire for food is shown particularly in the direction of fats, and secondarily of proteids.

For many years Voit's estimate, that a man of 154 to 165 pounds, working at moderately hard labor 9 or 10 hours a day, requires 118 grams of proteid, 56 of fat, and 500 of carbohydrates, the whole yielding 3054.6 calories, has been generally accepted as correct. Recently, however, Chittenden[3] has demonstrated conclusively by experiments extending over many months, the subjects being men engaged in intellectual pursuits, soldiers, and athletes in training, that half the stated amount of proteids is ample for the real physiological needs of the body under ordinary conditions of life, and that a fuel value of 3000 calories is not necessary, the diminution in the proteid intake requiring no additional amount of non-nitrogenous substances.

Knowing the composition of a given article of food, the proteid, fat, and carbohydrate value of a given weight can easily be determined; and thus one can construct standard dietaries for the various conditions

[1] Lehrbuch der Hygiene, Leipsic, 1900, p. 438. [2] Ibidem, p. 430.
[3] Physiological Economy in Nutrition, New York, 1904.

of bare subsistence, rest, and performance of various amounts of daily labor. Up to the present time it has been customary to prescribe the constituents of the standard diets in the following proportions: For each part of proteids, two-thirds of a part of fat, three and one-sixth parts of carbohydrates, and one-fourth of a part of mineral matter, the proportion of 1 part of nitrogen to 15 of carbon being maintained as nearly as possible. In view, however, of Chittenden's results, these proportions should be changed, not only on account of the fact that an excess of proteids is a burden to the system, but also for economical administration, since the nitrogenous foods are, as a class, by far the most expensive.

In any dietary, nutritive value must not be the sole consideration, for taste and variety are highly important and the palate must be flattered.

Composition of Foods.

The constituents of food materials are partly organic and partly inorganic. The organic constituents include proteids, fats, carbohydrates, and organic acids; the inorganic include water and mineral salts.

Proteids.—The proteids are the most important constituents of both animal and vegetable foods, and their presence is necessary for the carrying on of all the phenomena of life. They are very complex colloid substances composed of carbon, oxygen, hydrogen, nitrogen, and sulphur, possessing common properties and connected in very close genetic relationship. They are divided into animal proteids and vegetable proteids, but between the members of the one class and those of the other there are no important chemical differences, and they are about equal in nutritive value. Some of the vegetable proteids are not colloids, for according to Schmiedeberg, Weyl, Maschka, and others, they are found in crystalline form in the tissues of certain plants, and notably in the bean, pea, lentil, and various nuts.

Proteids when completely split up by acids yield as end products ammonia, nitrogen, organic bases, and amido acids. They are never completely absent from animal and vegetable tissues, but their amount in different substances is very widely variable, some foods being very rich in them, while in others they exist only in traces.

Ingested in great excess of the needs of the system, they are likely to cause general disturbance, diarrhœa and albuminuria, while a diet from which they are practically excluded will cause rapid loss of strength, anæmia, great prostration, and greatly diminished resistance to invasion by specific diseases, especially tuberculosis and pneumonia.

The animal proteids are more rapidly digested than the vegetable proteids, some of which are largely wasted through imperfect digestion. The proteids, whatever their source, yield in the main the same products of digestion, and consequently may replace each other in the diet.

The most complete classification of proteids is that of Wróblewski,[1] by whom they are divided into three groups as follows:

[1] Berichte der deutschen chemischen Gesellschaft, 1897, 30, pp. 3045, 3052.

Group I. Albuminous bodies closely related to egg albumin.

1. Albumins. Soluble in water. Egg albumin, serum albumin, lactalbumin, muscle albumin, vegetable albumin.

2. Globulins. Insoluble in water, soluble in dilute salt solution. Egg globulin (vitellin), serum globulin, lactoglobulin, fibrinogen, myosin, vegetable globulin.

3. Proteids soluble in alcohol. Substances very slightly soluble in water and salt solutions, soluble in dilute alcohol, some in strong alcohol. Chiefly of vegetable origin. Very rich in carbon.

4. Albuminates. Products of the action of alkalies on albumins. Slightly soluble in water, easily soluble in alkalies.

5. Acid albumins. Products of the action of acids on albumins. Soluble in very dilute acids and alkalies. Syntonin, etc.

6. Coagulated albumins. Proteid substances coagulated by the action of heat or enzymes. Fibrin, para-casein, etc.

Group II. Compound proteids composed of molecules which consist of an albumin group (a_1) plus another group, usually of a non-proteid nature.

1. Glyco-proteids. a_1 plus a carbohydrate group. Mucin, etc.

2. Hæmoglobins. a_1 plus a coloring-matter group.

3. Nucleo-albumins. a_1 plus a nuclein group.

4. Caseins. They contain no true nuclein group. With rennet they give a characteristic coagulation reaction. They are not coagulated by heat like albumin nor by enzyme action like fibrin. Milk casein, legumin, etc.

5. Nucleins. a_1 plus a nuclein acid group.

6. Amyloids.

Group III. Albuminoids.

a, Frame-work substances.

1. Keratins. Constituents of horn. Attacked with difficulty by pepsin and trypsin. They contain much sulphur and yield much tyrosin.

2. Elastins. Constituents of elastic tissue. They contain less sulphur and yield less tyrosin.

3. Collagens. Constituents of connective tissue, bone, and cartilage. They contain very little sulphur, and yield no aromatic amido-acids. Gelatin, isinglass, chondrin, collagen, etc.

b. Albumoses and Peptones. Products of hydrolytic splitting of various proteid substances. Their molecules are much smaller than those of the albumins.

c. Enzymes. Bodies which when present in very small amounts have the property of breaking up very large amounts of certain other substances, including proteids, fats, starches, etc.

The albumins are not precipitated by alkaline carbonates, common salt, or dilute acids, but they are coagulated by being heated to 65°–73° C. Casein, legumin, conglutin, syntonin, and albuminates, on the contrary, are not coagulable by heat, but are precipitated by common salt, sodium acetate, and trisodium phosphate. The albumoses are

widely distributed throughout the vegetable kingdom, and are found largely in the cereals. In the animal kingdom, they are intermediate products of the action of pepsin on ordinary proteids, becoming eventually converted to peptones. The collagens are very rich in nitrogen, but have an inferior nutritive value. Gelatin, for instance, contains 17–18 per cent., while the albumins contain but 16.

Fats.—The fats are compounds of the triatomic alcohol, glycerin, with fatty acids, mainly stearic, palmitic, and oleic. These several compounds are known as stearin, palmitin, and olein. The two first mentioned are solids at usual temperatures, while olein is a liquid. Most fats are combinations of two or all of these substances, and some, as, for example, butter, contain additional glycerides in small amount. Stearin and palmitin being solids, and olein liquid, the consistency of a fat is dependent upon the proportions in which these substances are present. Stearin is a component of most animal fats, but never is found in vegetable fats. The chief constituent of animal fats is palmitin, and this occurs also in nearly all vegetable fats. Olein exists in both. Butyrin, caprin, caproin, and caprylin are glycerides of volatile fatty acids present in the fat of milk.

Fats consist of carbon, hydrogen, and oxygen, and contain no nitrogen. The hydrogen and oxygen are not present in the proportions in which they exist in water and in carbohydrates, the oxygen being deficient.

As taken in food, fats are chiefly in the form of neutral substances, but more or less free fatty acid is always present, and in some foods which have been kept for a time, particularly in well-ripened cheese, fatty acids may be present in a free state in quite large proportion.

The fats play an important part in the maintenance of animal heat and mechanical energy. When hard labor is being performed, an excess of fat is instinctively taken.

Carbohydrates.—The carbohydrates include the starches, sugars, and cellulose.

The **Starches,** though presenting very different appearances under the microscope according to source, are of equal value as foods, and have the same composition. Starch is insoluble in water, but, heated with it to 72° C., the cells swell and burst, and produce a sort of mucilage. Heated with dilute mineral acids, it is converted into dextrose. Subjected to the action of diastase, it is converted into maltose.

Starch is found almost exclusively in vegetable cells. It forms the chief part of the seeds of the cereals and of the dried residue of certain other vegetable products, such as potatoes. A form of starch known as animal starch or glycogen is found in the liver and muscles, and also in some of the mollusca. Dextrin is an artificial product formed from starch by the action of ferments or of dilute acids and heat.

The **Sugars** are of vegetable and animal origin, and include the following:

1. Sucrose, cane sugar. A disaccharid. From sugar cane, sorghum, sugar maple, sugar beet, and some other vegetable sources. Insoluble

in strong alcohol, does not reduce copper; not directly fermentable. Boiled with dilute acids, is converted to invert sugar, a mixture of dextrose and lævulose.

2. Dextrose, glucose, grape sugar. A monosaccharid. Found in many fruits and flowers. Formed from cane sugar, maltose, starch, and dextrin by boiling with dilute acids. In the presence of decomposing proteids, splits into two molecules of lactic acid. Fermented with yeast, splits into alcohol and carbonic acid.

3. Maltose, malt sugar. A disaccharid. (Two molecules of dextrose.) Formed from starch by the action of diastase.

4. Lævulose, fruit sugar. A monosaccharid. Found in honey and various fruits. Rotates the ray of polarized light to the left. Does not form crystals. Isomeric with dextrose.

5. Lactose, milk sugar. A disaccharid. (Dextrose and galactose.) Found only in milk. Behaves like dextrose.

6. Galactose. A monosaccharid. Formed from lactose by boiling with dilute mineral acids.

7. Inosite, muscle sugar, phaseomannite. Found in certain animal tissues, as the heart's muscle, and in certain plants, as peas, beans, and grapes. Has no rotatory power, does not reduce copper, and is not fermentable. It contains the benzene ring, and hence is not a true sugar. In the presence of decomposing proteids, it is converted into lactic and butyric acids.

Cellulose.—Cellulose, while of value as a food for herbivora, has no nutritive value for man. It is converted to dextrose by boiling with dilute sulphuric acid.

Pectin.—Pectin is a substance not uncommonly classified as a carbohydrate. It is composed of carbon, hydrogen, and oxygen, but its precise composition is unknown. It is found in various fleshy fruits and in roots, and is believed to be formed from pectose by the action of vegetable acids. It is known also as vegetable jelly.

Pectose.—Pectose is an insoluble substance found in unripe fruits and roots: an earlier stage of pectin.

The carbohydrates play an important part in the maintenance of heat and the production of force. They lessen the need of fat and form fatty tissue. Excessive ingestion interferes with the metamorphosis of nitrogenous tissue, causes deposition of fat in excess, and is likely to produce digestive disturbances. Deprivation for a time can be borne, provided the system receives sufficient fatty food, but not otherwise.

Organic Acids.—The organic acids exist in foods either in the free state or in combination as salts. In the system they are converted to carbonates, which exercise a most important influence in controlling the alkalinity of the blood and other fluids. Deprivation leads to a peculiar disturbance of the system resulting in scurvy. They include malic, acetic, lactic, oxalic, citric, and tartaric acids. Malic acid is a constituent of apples, pears, and some other fruits. Acetic acid is the essential element of vinegar. Oxalic acid is found in considerable

amounts in spinach, tomatoes, strawberries, sorrel, and rhubarb. Lactic acid is present in fresh meats and in milk. The two most important acids are citric and tartaric. The former is found in oranges, lemons, limes, and other fruits; the latter largely in grapes.

Not all vegetables contain these acids, and, therefore, not all have antiscorbutic properties. Potatoes, cabbage, and roots are very efficient in this respect, while peas and beans are notable examples to the contrary.

Inorganic Salts.—The important inorganic salts taken into the system with food include sodium and potassium chlorides, sodium, potassium, magnesium and calcium phosphates, and compounds of iron. The sulphates are of minor importance and are ingested in only small amounts. The sulphur essential to growth is taken into the system in combination in the proteids. The chlorides keep the globulins of the blood and other fluids of the body in solution, and are the source of the hydrochloric acid of the gastric juice. The phosphates are very essential to the growth of bone and to the nervous system, and iron is needed for the hæmoglobin of the blood. Deficiency of calcium and magnesium salts leads to rickets and other abnormal conditions.

Section 2. ANIMAL FOODS: MEATS, FISH, EGGS, AND MEAT PRODUCTS.

The foods of animal origin used by man include the flesh and various organs of the herbivora and swine, domestic and wild fowl, eggs, fish and shellfish, milk and milk products. The flesh of all carnivorous animals except fish is unpalatable, and, therefore, undesirable as food, though under stress of circumstances it may be borne. Thus, during the siege of Paris, about 5,000 cats and 1,200 dogs are said to have been eaten when the food supply had become so meagre that anything in the form of flesh was acceptable. In Germany, according to a communication of Consul-General Guenther to the State Department at Washington, under date of May 26, 1900, the statistical year-book shows that, on account of the high price of other meats, not only horses, but also dogs are much used as food. At Breslau, Chemnitz, Dresden, Leipzig, Zwickau, and other places, dogs are slaughtered extensively for this purpose and regularly inspected.

Pirl[1] reports that in Saxony during 1894, 295; in 1895, 388; in 1896, 399; and in 1897, 474 dogs were slaughtered and inspected. In Dessau, between 1893 and 1898, the number averaged 251 yearly, and inspection showed that one in 202 was trichinous. According to Tempel,[2] of 289 killed at Chemnitz during 1897, 1.391 per cent., and of 147 killed during the first half of the year 1898, 2.04 per cent. were found to be trichinous. The meat is eaten chiefly in the roasted state, but also, in many parts of Saxony, raw, but highly sea-

[1] Zeitschrift für Fleisch- und Milchhygiene, X., No. 1.
[2] Ibidem, IX., No. 1.

soned. The same animals are commonly eaten by the Chinese, and the Canada lynx and the skunk are rated as delicacies by the North American Indians.

MEATS.

The value of meat as food depends upon the presence of proteids, fat, and mineral salts. The nitrogenous extractive matters (creatin, etc.), sometimes called "meat bases," formed by cleavage of the proteids, give flavor, but have little value as foods. The carbohydrates play but an insignificant part, being present chiefly as muscle sugar and to only a very small extent. All meat, however lean, contains fat, some of which is visible and some indistinguishable from the muscle fibres by which it is surrounded. The visible fat varies widely in amount. Very fat beef may contain considerably more than a quarter of its weight of visible fat, and fat pork meat more than a half, while chicken and veal contain comparatively little.

The content of water varies very widely and in general may be said to be governed by the richness in fat, for, while the proteids are fairly constant in amount, the remainder is almost wholly water and fat, and the greater the amount of the one, the less the amount of the other. The less fat a meat contains, the less, therefore, its relative nutritive value.

Digestibility.—While the amount of nutriment contained in meats chiefly determines their food value, the latter is to no inconsiderable extent dependent upon the ability of the alimentary tract to digest and absorb them. Gastric digestion is by no means to be accepted as a measure of the true digestibility of a food, and the same is true of the results of artificial laboratory experiments; hence many of the accepted statements bearing on this subject, based upon the oft-quoted experiments on Alexis St. Martin and upon test-tube observations, may be wholly disregarded.

Raw meat is digested more easily, but less completely, than that which has undergone the process of cooking, and roasted meat is more completely digested than that which has been boiled. Fat meats, as beef and mutton, and especially pork, require more time for digestion than those which, like chicken and veal, contain but little fat. In general, it may be said that meats are assimilated more easily than vegetable foods.

Flavor.—The flavor of meats depends largely upon the nature and amounts of nitrogenous extractives which they contain, and is greatly modified by the condition of the animal when killed, its age, sex, and the character of its food. The high flavor of birds and game is due to the richness in extractives, while in the case of meats deficient in these substances, as, for example, mutton and pork, the flavor is due largely to their contained fats. Most meats are improved in flavor by being kept for a time, during which, additional flavors, due to decomposition products similar to the extractives, are developed. The meat of young animals is flavored less highly than that of adults, and

that of females than that of males, though in the case of the goose this condition is reversed, and in that of swine no difference is observable.

Asexualization by spaying or castration produces a fatter, more tender, and better flavored meat. Thus, the flesh of oxen is far preferable to that of bulls or cows, and that of capons and poulards to that of cocks and hens.

Texture.—Whether a given meat is tough or tender depends upon the character of the walls of the muscle tubes and upon the amount of connective tissue present. The tube walls are thin and delicate, and the connective tissue is small in amount in the young and well-fed, but as the animal becomes older or is made to work, the tubes thicken and become hard, the connective tissue increases in amount, the fat may diminish, and the result is a coarser flesh. Very young animals have a very watery, gelatinous, and flavorless flesh.

The texture of meat undergoes very considerable change after slaughter. When freshly slaughtered, it is tender and juicy, but as rigor mortis supervenes, it becomes hardened and tough. The stage of rigor is succeeded by the first stage of decomposition, during which lactic acid is formed. This acts upon the connective tissue and causes softening and tenderness, and as the process of decomposition proceeds within proper limits, increase of flavor is developed.

Effects of Cooking.—When meat is cooked, the connective tissue is softened, the bundles of fibrillæ are loosened from each other, the albumin is coagulated, flavors are improved and new ones developed, parasites and micro-organisms are destroyed, and the whole mass is rendered more acceptable to the eye and palate. In the process of **roasting** or **broiling**, considerable shrinkage due to loss of water occurs. The heat to which the meat is subjected should be sufficiently intense to produce speedy coagulation of the exterior and prevent the meat juices from becoming dried up. In order that the surface shall not be burned, the meat must be basted from time to time with hot melted fat, which forms a protective coating. The heat employed should be less intense with large joints than with small ones, since before the heat can penetrate well into the interior, the outer parts will become burned.

In **boiling**, the temperature of the water into which the meat is immersed varies according to the object sought. If a rich broth is desired, the meat is placed in cold water, which then is heated gradually. During the heating process, the soluble albumins together with a portion of the salts and the extractives are dissolved out. When the temperature reaches 134° F., the albumin begins to coagulate, and above 160°, the connective tissue is changed to gelatin and dissolved. The solution of certain of the constituents is assisted by the small amounts of lactic acid formed.

If, on the other hand, it is desired to have the juices and flavors retained within the mass, the meat should be plunged into boiling water, which quickly coagulates the albumins at the surface and causes thereby the formation of a protective coating. After this is formed, the tem-

perature should be lowered to about 180° F., for otherwise the meat becomes tough, even to the center. The shrinkage in meat that has been properly boiled amounts to from 20 to 40 per cent. of its weight.

In **frying**, the meat is dropped into very hot fat, as lard or vegetable oil, which causes speedy coagulation of the surface, such as is brought about in the process of boiling, whereby all the flavors and juices are retained. It is essential that the fat be very hot, since otherwise it will penetrate the tissues and cause the meat to become greasy and unpalatable.

In **stewing**, the meat is cut into small pieces and placed in cold water, which then is heated slowly to about 180° F., at which temperature the whole is kept for several hours. If heated above 180°, the meat becomes tough, stringy, unpalatable, and of diminished digestibility.

Characteristics of Good Meat.—Meat should have a uniform color, neither abnormally pale nor inclined to purplish. It should have little or no odor, and such as it has should give no disagreeable impression such as the sickly cadaveric smell characteristic of diseased or decomposing flesh. It should be firm and elastic, and should not pit nor crackle on pressure. On being handled, it should scarcely moisten the fingers, and with keeping, the exterior should become dry rather than wet. There should be no evidence whatever of the presence of parasites.

Beef has a bright red color and a marbled appearance, due to the presence of fat between the bundles of muscular fibers. This marbling is much less apparent in the flesh of animals that have not been well fed and of old cows and bulls. Bull meat is darker than that of oxen and cows, and is coarse, stringy, and of strong flavor.

Veal is much paler than beef and less firm to the touch, and coming from a very young animal, "bob-veal," it is flabby and watery, and its fat has a tallowy appearance.

Mutton should be of a dull-red color and firm to the touch. Its fat is white, sometimes yellowish, and hard.

Lamb is somewhat less firm to the touch and has a decidedly lighter color than mutton.

Pork is much less firm to the touch than beef and mutton, and its fat is quite soft in comparison.

Horse meat, the use of which is increasing rapidly abroad and to a much greater extent in this country than is commonly believed, is darker and coarser than beef and possesses a very different odor. The fat is yellow and oily and has a rather disagreeable odor.

The flesh of birds is not marbled like that of mammals. That of wild fowl that feed on fish has a strong flavor, which is not improved by keeping.

Comparative Digestibility of Meats.—Beef is commonly and correctly regarded as one of the most digestible of meats, but according to the experience and testimony of many victims of dyspepsia it is inferior in this respect to mutton. Pork is, without doubt, digested with greater difficulty than any other meat, on account of its high content of fat. The evidence as to veal is most conflicting, some holding that

it is digested very easily, while others maintain the contrary view. Certain it is that many persons bear it very badly. The white meat of chickens, fowls, and turkeys, is more delicate and is digested more easily than the dark meat, probably by reason of its smaller amount of fat. The flesh of ducks and geese is harder, richer, and more difficult of digestion. Game birds are less fat than poultry and are often much better borne. Their habits of life are unfavorable to the deposition of much fat. Liver, kidneys, and heart are generally regarded as unsuitable as foods for persons with weak stomachs, but tripe and sweetbreads are usually easily borne.

"Red Meat" and "White Meat."—The prohibition of red meats (beef, mutton, venison) to patients with gouty and rheumatic tendencies dates from the time of Sydenham, whose dietetic rules allowed only the white meats (veal, goat, young pig, chicken) and fish to such persons. Today, many practitioners extend this prohibition to those with diseases of the stomach, intestines, and kidneys, and various neuroses. The foundation of this prejudice against the red meats is the supposed presence in them of a greater percentage of the nitrogenous extractives (creatin, xanthin, guanin, etc.), which are believed to exert injurious action in two ways: First, locally, by irritating the kidneys during the process of their elimination from the body; and second, in cases of impaired functional activity of the kidneys, by causing systemic intoxication. Unfortunately, however, for the stability of this belief, exact analysis has shown that the very small amounts of these substances present are practically the same in both red and white meats, with the single exception of venison, which contains them not, as would be surmised, in highest percentage, but, in fact, in lowest. Furthermore, these extractives are not eliminated as such, but as the normal ultimate product of metamorphosis, urea. It has been supposed, too, that the non-nitrogenous extractives (lactic, butyric, and acetic acids, etc.) are present to a greater extent in red than in white meats and may cause disturbance; but as a matter of fact, these are present in extremely small amounts in both red and white meat, and cannot possibly be regarded as harmful, in view of the fact that appreciable amounts exert no influence on the system.

Composition of Meats.—In the following tables, showing the composition of the edible portions of meats, the figures given are taken, unless otherwise stated, from Bulletin No. 28 (revised edition) of the Office of Experiment Stations of the U. S. Department of Agriculture: The Chemical Composition of American Food Materials.[1]

[1] Government Printing Office, Washington, 1899.

BEEF.

Cut.	Number of Analyses.	Water.	Proteids.	Fat.	Ash.	Fuel value per pound. (Calories.)
Brisket, medium fat	3	54.6	15.8	28.5	0.9	1495
Chuck, including shoulder.						
very lean	1	73.8	22.3	3.9	0.8	580
lean	2	71.3	20.2	8.2	1.0	720
medium fat	4	68.3	19.6	11.9	0.9	865
fat	4	62.3	18.5	18.8	0.9	1135
very fat	2	53.2	17.2	29.0	0.9	1555
Average	13	65.0	19.2	15.4	0.9	1005
Chuck rib, very lean	1	75.8	22.2	1.4	1.1	470
lean	11	71.3	19.5	8.3	1.0	715
medium fat	7	62.7	18.5	18.0	1.0	1105
fat	2	52.0	16.6	31.1	0.8	1620
Average	21	66.8	19.0	13.4	1.0	920
Flank, very lean	3	70.7	25.9	3.3	1.2	620
lean	3	67.8	20.8	11.3	1.0	865
medium fat	5	60.2	18.9	21.0	0.9	1240
fat	3	54.2	17.1	28 4	0.8	1515
very fat	2	34.7	14.0	51.8	0.7	2445
Average	16	59.3	19.6	21.1	0.9	1255
Loin, very lean	3	70.8	24.6	3.7	1.3	615
lean	12	67.0	19.7	12.7	1.0	900
medium fat	32	60.6	18.5	20.2	1.0	1190
fat	6	54.7	17.5	27.6	0.9	1490
very fat	3	49.7	17.8	32.3	0.9	1695
Average	56	61.3	19.0	19.1	1.0	1155
Porterhouse steak	7	60.0	21.9	20.4	1.0	1270
Sirloin steak	21	61.9	18.9	18.5	1.0	1130
Top of sirloin	1	42.2	13.8	43.7	0.8	2100
Tenderloin	6	59.2	16.2	24.4	0.8	1330
Ribs, very lean	4	65.7	21.9	1.1	0.7	455
lean	6	67.9	19.6	12.0	1.0	870
medium fat	15	55.5	17.5	26.6	0.9	1450
fat	9	48.5	15.0	35.6	0.7	1780
very fat	1	45.9	14.6	38.7	0.6	1905
Average	35	57.0	17.8	24.6	0.9	1370
Rib rolls, very lean	2	73.7	20.8	5.0	1.0	600
lean	3	69.0	20.2	10.5	1.0	820
medium fat	4	63.9	19.3	16.7	0.9	1065
fat	2	51.5	17.2	31.3	0.8	1640
Average	11	64.8	19.4	15.5	0.9	1015
Round, very lean	6	73.6	22.6	2.8	1.3	540
lean	31	70.0	21.3	7.9	1.1	730
medium fat	18	65.5	20.3	13.6	1.1	950
fat	5	60.4	19.5	19.5	1.0	1185
very fat	2	55.9	18.2	26.2	0.8	1445
Average	62	67.8	20.9	10.6	1.1	835
Round, second cut	2	69.8	20.4	8.6	1.1	740
Rump, very lean	4	71.2	23.0	5.1	1.2	645
lean	4	65.7	20.9	13.7	1.0	965
medium fat	10	56.7	17.4	25.5	0.9	1400
fat	5	47.1	16.8	35.7	0.8	1820
very fat	1	40.2	15.0	44.3	0.8	2150
Average	24	57.9	18.7	23.1	0.9	1325

BEEF.—*Continued.*

Cut.	Number of Analyses.	Water.	Proteids.	Fat.	Ash.	Fuel value per pound. (Calories.)
Beef heart	2	62.6	16.0	20.4	1.0	1160
Kidney (carbohydrates 0.4)	3	76.7	16.6	4.8	1.2	520
Liver (carbohydrates 1.5)	6	71.2	20.7	4.5	1.6	605
Marrow	1	3.3	2.2	92.8	1.3	3955
Tongue	3	70.8	18.9	9.2	1.0	740
Lungs	1	79.7	16.4	3.2	1.0	440
Suet	9	13.7	4.7	81.8	0.3	3540
Roast beef (cut not specified)	7	48.2	22.3	28.6	1.3	1620
Sirloin steak, baked	1	63.7	23.9	10.2	1.4	875
Broiled tenderloin	6	54.8	23.5	20.4	1.2	1300
Round steak	18	63.0	27.6	7.7	1.8	840
Canned corned beef	15	51.8	26.3	18.7	4.0	1280
Canned roast beef	4	58.9	25.9	14.8	1.3	1105
Canned whole tongue	5	51.3	19.5	23.2	4.0	1340
Canned tripe	2	74.6	16.8	8.5	0.5	670
Corned beef (all cuts)	10	53.6	15.6	26.2	4.9	1395
Tongues, pickled	2	62.3	12.8	20.5	4.7	1105
Tripe (carbohydrates 0.2)	4	86.5	11.7	1.2	0.3	270

PORK.

Cut.	Number of Analyses.	Water.	Proteids.	Fat.	Ash.	Fuel value per pound. (Calories.)
Ham, fresh, lean	2	60.0	25.0	14.4	1.3	1075
medium fat	10	53.9	15.3	28.9	0.8	1505
fat	5	38.7	12.4	50.0	0.7	2345
visible fat largely removed	3	64.5	19.2	16.2	0.9	1040
Loin (chops), lean	1	60.3	20.3	19.0	1.0	1180
medium fat	19	52.0	16.6	30.1	1.0	1580
fat	4	41.8	14.5	44.4	0.7	2145
Tenderloin	11	66.5	18.9	13.0	1.0	900
Shoulder	19	51.2	13.3	34.2	0.8	1690
Feet	8	50.7	8.3	17.4	0.4	1090
Head cheese	3	43.3	19.5	33.8	3.3	1790
Kidney	2	77.8	15.5	4.8	1.2	490
Liver (carbohydrates 1.4)	1	71.4	21.3	4.5	1.4	615
Ham, smoked, lean	3	53.5	19.8	20.8	5.5	1245
medium fat	14	40.3	16.3	38.8	4.8	1940
fat	4	27.9	14.8	52.3	3.7	2485
smoked, boiled	2	51.3	20.2	22.4	6.1	1320
Shoulder, smoked, medium fat	3	45.0	15.9	32.5	6.7	1665
fat	2	26.5	15.1	53.6	5.2	2545
Salt pork, fat	7	7.9	1.9	86.2	3.9	3670
lean ends	4	19.9	8.4	67.1	5.7	2985
Bacon, smoked, lean	2	31.8	15.5	42.6	11.0	2085
medium fat	17	18.8	9.9	67.4	4.4	3030

VEAL.

Cut.	Number of Analyses.	Water.	Proteids.	Fat.	Ash.	Fuel value per pound. (Calories.)
Breast, lean	5	72.1	21.7	5.6	1.1	640
medium fat	7	66.0	19.5	14.0	1.0	955
Leg, lean	9	73.5	21.3	4.1	1.2	570
medium fat	10	70.0	20.2	9.0	1.2	755
cutlets	3	70.7	20.3	7.7	1.1	705
Loin, lean	5	73.3	20.4	5.6	1.2	615
medium fat	6	69.0	19.9	10.8	1.0	825
fat	2	61.6	18.7	18.9	1.0	1145
Heart	1	73.2	16.8	9.6	1.0	720
Kidney	2	75.8	16.9	6.4	1.3	585
Liver	2	73.0	19.0	5.3	1.3	575

MUTTON.

Cut.	Number of Analyses.	Water.	Proteids.	Fat.	Ash.	Fuel value per pound. (Calories.)
Hind leg, lean	3	67.4	19.8	12.4	1.1	890
medium fat	11	62.8	18.5	18.0	1.0	1105
fat	1	55.0	17.3	27.1	0.9	1465
Loin, medium fat without kidney and tallow	13	50.2	16.0	33.1	0.8	1695
fat without kidney and tallow	3	43.3	14.7	41.7	0.8	2035
very fat without kidney and tallow	1	30.8	10.6	58.7	0.5	2675
Fore quarter	10	52.9	15.6	30.9	0.9	1595
Hind quarter	10	54.8	16.7	28.1	0.8	1495
Roast leg, cooked	2	50.9	25.0	22.6	1.2	1420
Kidney	1	69.5	16.9	12.6	0.9	845
Liver (carbohydrates 5.0)	2	61.2	23.1	9.0	1.7	905

LAMB.

Cut.	Number of Analyses.	Water.	Proteids.	Fat.	Ash.	Fuel value per pound. (Calories.)
Hind leg, medium fat	2	63.9	19.2	16.5	1.1	1055
fat	1	54.6	18.3	27.4	0.9	1495
very fat	1	51.8	17.6	30.1	0.9	1595
Loin, without kidney and tallow	4	53.1	18.7	28.3	1.0	1540
Fore quarter	1	55.1	18.3	25.8	1.0	1430
Hind quarter	1	60.9	19.6	19.1	1.0	1170
Broiled chops	4	47.6	21.7	29.9	1.3	1665
Roast leg	1	67.1	19.7	12.7	0.8	900

POULTRY.

Cut.	Number of Analyses.	Water.	Proteids.	Fat.	Ash.	Fuel value per pound. (Calories.)
Broiler chickens	3	74.8	21.5	2.5	1.1	505
Fowls	26	63.7	19.3	16.3	1.0	1045
Young goose	1	46.7	16.3	36.2	0.8	1830
Turkey	3	55.5	21.1	22.9	1.0	1360
Chicken liver (carbohydrates 2.4)	1	69.3	22.4	4.2	1.7	640
Goose liver	1	73.8	19.6	5.8	1.0	610

Horse Meat.—The mean of twelve analyses of horse meat as given by König[1] is as follows:

Water	74.27
Proteids	21.71
Fat	2.55
Ash	1.01

The objection to the use of horseflesh as food is very largely sentimental. It has not the pleasant flavor of beef, to which we are accustomed, but when eaten in ignorance of its true character, it makes no unpleasant impression. Its use is increasing steadily in Europe, and is finding favor in America. In Paris, during 1898, 21,667 horses, 52 mules, and 310 donkeys were slaughtered for food, and of these but 734 horses, 1 mule, and 7 donkeys were condemned as unsalable. The meat was disposed of in 193 shops, where the best cuts brought about a franc (19.3 cents), and the inferior parts 10 centimes (2 cents) per pound. During 1896, 822 horses and mules were slaughtered in Strassburg, and in 1898 the number rose to 1,099. In Vienna, where the sale of the meat was permitted first in 1854, there were slaughtered, in 1899, 25,646 horses and 58 donkeys. In the whole of Prussia, there were slaughtered, in 1897, at 367 abattoirs, 58,484 horses, and in the following year the number rose to 63,531. In Frankfort, where, in 1847, the first horse-meat dinner ever given occurred, about a thousand horses are slaughtered annually, at a special abattoir. In the United States, during 1899, 3,232 horses were slaughtered and officially inspected with other food animals.

It is said that, unless the fat of some other animal or some starchy food is eaten with it, horse meat may cause diarrhœa. Whatever causes this disturbance is soluble in water, and may thus be removed partially when the meat is boiled. From water in which horse-meat had been boiled, E. Pflüger[2] separated jecorin, lecithin, and (probably) neurin. He recommends the addition of about 25 grams of beef or mutton kidney-fat to each kilogram of the meat when a mince is to be made, and that, in whatever form it is consumed, it be served with a fat gravy.

[1] Zusammensetzung der menschlichen Nahrungs- und Genussmittel, Berlin, 1882.
[2] Archiv für die gesammte Physiologie, 1900, Bd. 80, p. 111.

Meat Preparations.—Meat Extracts.—These are preparations which are supposed often erroneously to contain all the nutritive parts of the meats from which they are made, but they are to be regarded as stimulants rather than foods, since they represent the extractives and not the substances which determine the true food value. In point of fact, so far as their nutritive properties are concerned, it has been shown that animals will die more quickly of starvation when fed exclusively upon these stimulating preparations than when entirely deprived of food. They are, however, of considerable value in their proper place, particularly in conditions of great fatigue and exhaustion.

Meat Powder.—Meat may easily be treated so as to retain all of its nutriment and yet have a very much diminished volume. The lean parts are cut into small strips, dipped for a few minutes into very hot fat (fried), drained, and then slowly dried in an oven. When completely dry, they are ground in an ordinary spice mill or coffee mill to a fine powder, which keeps well, has an agreeable taste and a pleasant odor, is digested easily, and may be used in a great many different ways.

Sausages.—Sausage is understood generally to mean an article of food consisting chiefly of finely chopped meat, mainly pork and beef, with or without the addition of a small amount of meal, highly seasoned with spices, herbs, and other flavorings, and stuffed into casings made from cleaned and prepared intestines. Their nutritive value is, therefore, about the same as that of average meat. As may be supposed, the best cuts of meat are not used in their manufacture, but only such parts as cannot be disposed of in pieces of fair size and of attractive appearance. But there are sausages and sausages. There are those made from meat of good quality and others from materials which would not be salable in any other form.

Many of the so-called Frankforters, sold at very low rates, and the cheap Bolognas are said to consist largely of horse meat, immature veal, and the flesh of cows that are no longer in condition to produce milk. Certain it is that a not inconsiderable number of persons gain a fair livelihood by going about in the country buying up newly born calves and decrepit cows, tuberculous and otherwise, and horses, and that these animals are not taken to comfortable stables and inviting pastures, but to small slaughtering establishments, the output of which is not very largely butchers' meat. To the cheap grades of sausages the saying of Jean Paul, "Only a god can eat sausage, for only such can know of what it is made," applies very aptly. Even sausages made from pork, especially those which have undergone a process of cooking before being stuffed, are not always beyond suspicion, for the trichinous pork condemned by government inspectors at public abattoirs is neither destroyed nor converted into fertilizers, but is allowed to be sold after being subjected to a heat sufficient to kill the parasites; and cooked pork is not commonly to be found on sale as such.

Horse meat is said to combine two advantages in the preparation of sausage: it is inexpensive, and it lends a firmness which increases as the sausage is boiled. A number of chemical processes have been pro-

posed for its detection, and among them the following: Dr. Nötel[1] covers coarsely chopped horsemeat with a 0.1 per cent. solution of sodium hydroxide, lets the mixture stand 3 hours at 37° C., and then separates the liquid through cheese cloth. The liquid is injected, in doses of 8 to 10 cc., subcutaneously into a rabbit at intervals of 2 or 3 days until 10 or 12 injections have been given. Six days after the last injection, the animal is bled and its serum serves as a reagent. The suspected food is chopped finely, covered with 0.1 per cent. sodium hydroxide, allowed to stand 2 hours in a warm room, and filtered. A few drops of the filtrate are mixed in a test-tube with about an equal amount of the serum, and other tubes containing filtrate alone are used as controls. The tubes are incubated at 37° C., and if the suspected article contains horsemeat, the tubes containing the serum will become cloudy in from 10 to 40 minutes.

A number of tests which depend upon the reaction of iodine with glycogen, which is a normal constituent of horsemeat, are criticised by Niebel[2] as uncertain, on account of the presence of glycogen in liver, meat extract, and very young veal.

In the manufacture of all grades of sausage, scrupulous care should be observed to secure cleanliness of the casings, which require more thorough treatment than the mere passage of water through them. Dr. Schilling[3] reports the examination of prepared intestines which yielded 5 grams of excrement per meter.

Owing to the occurrence of a gray color, which is said by Meyer[4] to be due to the passage of salt by diffusion from the contents to the casing, which is rich in water and poor in salt, the commercial value of certain varieties of sausage is impaired, and hence it becomes necessary to apply artificial colors, or so to treat the stuffing that the change in color shall not occur. The very red appearance which so often suggests the presence of coal-tar products may be due to the action of harmless preservatives, like niter, or the hæmoglobin of swine blood. In such case, the extract with alcohol, glycerin, or amyl alcohol will not dye wool, and the color cannot be precipitated as a lake.

According to J. Haldane,[5] the red color of cooked salted meats is due to the presence of NO-hæmochromogen produced by the decomposition of NO-hæmoglobin, which is formed by the action of a nitrite on the NO-hæmochromogen in the absence of oxygen and presence of reducing agents. The nitrite is formed by reduction, within the raw meat, of the niter used in salting.

Certain of the artificial sausage colors, as "Orange II.," the sodium salt of β-naphtholazobenzene, are extracted easily with acidulated water, and will dye woolen fibers immersed therein.

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXXIX., p. 373.
[2] Zeitschrift für Fleish- und Milchhygiene, 1895, p. 86.
[3] Deutsche medicinische Wochenschrift, 1900, p. 602.
[4] Chemiker Zeitung, 1900, p. 3.
[5] Journal of Hygiene, 1901, Vol. I., p. 115.

FISH.

In the ordinary sense of the word, fish includes, in addition to the varieties of fish in its narrow sense, mollusks (clams, oysters, mussels, etc.) and crustaceans (lobsters, crabs, crawfish, and shrimps).

Many prejudices have existed from the earliest times, and to a certain extent still exist, against the use of fish in the diet. The ancient belief that a fish diet is a common cause of leprosy still obtains to a certain extent, even among enlightened people, in spite of all scientific evidence to the contrary. Thus, Mr. Jonathan Hutchinson[1] maintains that this disease is so caused, especially if the fish is poorly cooked or partially decomposed. He asserts that the disease prevails near the sea and is disappearing before the advance of agriculture; but opposed to this is the fact that, in the interior of India, the disease is very common among people whose religion forbids the use of fish, and who cannot obtain it even if it were desired.

Some varieties of fish cannot be eaten, because of their inherent poisonous properties. But few of these are, however, found north of the tropics. Some of them are always poisonous, and others only at certain times; and in some cases, individuals of certain species may be and others may not be noxious. Some varieties of fish are the hosts of parasites, some of which are injurious to man, but unless eaten in the raw state they are not likely to produce harm.

There is a belief that fish is particularly valuable as a brain food, on account of the supposed high percentage of phosphorus that it contains. The amount of phosphorus is, however, so far as is known, no higher in fish than in meat and, moreover, this element is no more essential to the brain and nervous system than any others which are present. If there were any truth in this common belief, we should expect naturally to find men of commanding intellect among those whose diet consists mainly of fish, but, as is well known, such people are of a low order of intelligence, though not by reason of their diet.

In spite of the large amount of nutriment contained, fish has not the same satisfying properties that belong to meats, but it is an exceedingly valuable food, and in many parts of northern countries is the principal animal food. The flavor of fish is influenced greatly by the nature of the food supply and by the content of fat. Generally speaking, salt-water fish from deep water, where the current is strong, are better than those from shallow, warm, and quiet water, and both salt-water and fresh-water fish taken from rocky and sandy bottoms are preferred to those from muddy bottoms.

Condition is dependent upon a variety of circumstances. Some fish are regarded most highly during their spawning season (shad and smelts), while others are looked upon with disfavor at this period. Fish caught by the gills in gill nets die slowly, but decompose rapidly, and such are of inferior flavor and value. Fish taken from the water

[1] Archives of Surgery, April, 1899.

alive and killed at once remain firm and retain their flavor longer than those allowed to die slowly.

Digestibility.—So far as is known, the digestibility of fish and meat is about equal, but, as is true of meats, different varieties of fish are differently digestible. Thus, those which contain the greatest percentages of fat, as salmon, eels, and mackerel, are the most difficult of digestion. The processes of drying, smoking, salting, and pickling lessen digestibility, and fish so treated are, in consequence, less suited to the needs of invalids and dyspeptics. The mollusks are regarded generally as most digestible, while the crustaceans are believed to tax the digestive powers much more than any other animal food. Many persons are unable to digest them in any form, and others who suffer no inconvenience, so far as digestion is concerned, are obliged to practise self-denial, because of idiosyncrasy, which manifests itself in distressing eruptive disorders of the skin, dizziness, and other nervous symptoms. Lobster and crabs are much alike, but the former is less likely to disagree. The claws of the lobster are more tender and delicate than the tail, which is firmer and much closer grained. Shrimps are rated generally as more difficult of digestion than lobsters and crabs, but with many they are borne more easily.

The mollusks are more digestible in the raw state than when cooked. The comparatively tough part of the oyster, the adductor muscle, is very trying to some persons, and for such it is best removed and rejected.

Keeping Qualities.—Fish flesh differs very greatly from meats in keeping qualities. While the latter are improved up to a certain point by hanging, fish should be eaten while fairly fresh, since decomposition sets in very quickly. Some varieties, as halibut, cod, haddock, and turbot, may be kept a week or more when properly cared for, while others begin to deteriorate almost immediately. So long as the flesh is firm and stiff, all fish is edible, but when it is crushed readily by gentle pressure between the fingers, it is unsound and should be rejected. Mollusks and crustaceans decompose very quickly, and the latter when boiled a short time after natural death have but little flavor.

Composition.—In proteids, fish rank nearly as high as meats, but they are very much poorer in fat, only a few varieties yielding over 10 per cent. These include salmon, turbot, lamprey eels, eels, butterfish, lake trout, and herring, and are followed by shad and Spanish mackerel, with over 9 per cent. The great majority of species contain less than 5 per cent., and many of the commoner kinds even less than 1 per cent. In fact, most fish flesh yields more mineral matter than fat. Shellfish are fairly rich in proteids and contain notable amounts of carbohydrates, but they are very poor in fat.

The chemical composition of the edible portions of many varieties of American fish is given in the following table compiled from the report of the U. S. Commissioner of Fish and Fisheries for 1888:

Kinds of fish.	In flesh.					
	Proteids.	Fat.	Ash.	Total.	Water.	Fuel value per pound.
	per ct.	per ct.	per ct.	per ct.	per ct.	Calories.
California salmon	17.46	17.87	1.06	36.39	63.61	1,080
Eel	15.82	18.74	0.93	35.49	64.51	1,085
Salmon	20.77	12.09	1.38	34.24	65.76	895
Spanish mackerel	20.97	9.43	1.50	31.90	68.10	790
Lake trout	18.22	11.38	1.26	30.86	69.14	820
Whitefish	22.06	6.49	1.62	30.17	69.83	685
Butterfish	17.81	11.03	1.14	29.98	70.02	795
Shad	18.55	9.48	1.35	29.38	70.62	745
Lamprey eel	14.93	13.29	0.66	28.88	71.12	840
Turbot	12.92	14.41	1.28	28.61	71.39	850
Mackerel	18.77	8.21	1.40	28.38	71.62	695
Herring	18.19	8.02	1.69	27.90	72.10	675
Pompano	18.65	7.57	1.00	27.22	72.78	665
Alewife	19.17	4.92	1.47	25.56	74.44	565
Small-mouthed black bass	21.50	2.44	1.24	25.18	74.82	505
Halibut	18.35	5.18	1.05	24.58	75.42	560
Sheepshead	19.54	3.69	1.22	24.45	75.55	520
White perch	19.03	4.07	1.19	24.29	75.71	525
Pollock	21.65	0.78	1.55	23.98	76.02	435
Cisco	19.12	3.48	1.25	23.85	76.15	505
Muskellunge	19.63	2.54	1.57	23.74	76.26	470
Striped bass	18.31	2.83	1.16	22.30	77.70	460
Brook trout	18.97	2.10	1.21	22.28	77.72	440
Red snapper	19.20	1.03	1.31	21.54	78.46	400
Bluefish	19.02	1.25	1.27	21.54	78.46	405
Large-mouthed black bass	19.24	0.96	1.19	21.39	78.61	400
Small-mouthed red-horse	17.90	2.35	1.19	21.44	78.56	430
Sturgeon	17.96	1.90	1.43	21.29	78.71	415
Skate	18.82	0.93	1.43	21.18	78.82	390
Weakfish	17.45	2.39	1.19	21.03	78.97	425
Blackfish	18.47	1.35	1.08	20.90	79.10	400
Smelt	17.36	1.80	1.68	20.84	79.16	400
Kingfish	18.66	0.95	1.18	20.79	79.21	385
Sea bass	18.75	0.49	1.44	20.68	79.32	370
Grouper	18.80	0.60	1.15	20.55	79.45	375
Yellow perch	18.49	0.70	1.29	20.48	79.52	375
Pike perch, Wall-eyed pike	18.42	0.47	1.37	20.26	79.74	360
Pickerel	18.64	0.50	1.18	20.32	79.68	370
Pike perch, Gray pike	17.26	0.76	1.13	19.15	80.85	355
Haddock	17.10	0.26	1.25	18.61	81.39	330
Tomcod	17.08	0.38	0.99	18.45	81.55	335
Red bass	16.68	0.53	1.23	18.44	81.56	335
Cusk	16.92	0.17	0.90	17.99	82.01	320
Cod	16.00	0.30	1.24	17.54	82.46	310
Hake	15.24	0.67	0.98	16.89	83.11	310
Common flounder	13.82	0.69	1.28	15.79	84.21	285
Winter flounder	14.01	0.44	1.20	15.65	84.35	280
Spent fish.						
Spent salmon	18.52	3.60	1.14	23.26	76.74	495
Spent land-locked salmon	17.24	2.98	1.24	21.46	78.54	445

Fish.	Edible portion.						
	Nutrients.				Water.	Energy in 1 pound.	Salt.
	Proteids.	Fat.	Ash.	Total.			
	per ct.	per ct.	per ct.	per ct.	per ct.	Calor.	per ct.
Desiccated codfish (fish meal)	74.46	1.90	5.41	84.75	15.25	1,465	2.88
Salt codfish	21.42	0.34	1.62	46.42	53.58	410	23.04
Salt mackerel	18.88	25.12	2.59	56.99	43.01	1,410	10.40
Smoked haddock	33.68	0.17	1.53	27.44	72.56	445	2.06
Smoked halibut	20.57	15.03	2.06	50.62	49.38	1,015	12.96
Smoked herring	36.44	15.82	1.53	65.45	34.55	1,345	11.66
Canned salmon	20.06	15.70	1.32	38.12	61.88	1,035	1.04
Canned mackerel	19.91	8.68	1.30	31.82	68.18	735	1.93
Canned tunny	21.52	4.05	1.69	27.26	72.74	570	

Fish.	Proteids.	Fat.	Carbo-hydrates.	Ash.	Total.	Water.
Oysters	9.78	2.05	5.89	1.98	19.70	80.30
Oyster liquor	1.48	0.03	0.75	2.13	4.39	95.61
Canned oysters	7.41	2.07	3.95	1.31	14.74	85.26
Long clams	14.55	1.79	2.94	2.76	22.04	77.96
Long clams (canned)	17.73	2.89	1.59	3.16	25.37	74.63
Round clams	11.59	0.74	7.21	2.22	21.76	78.24
Round clams (canned)	16.70	1.27	4.14	2.33	24.44	75.56
Mussels	12.51	1.67	5.42	1.73	21.33	78.67
Scallops	14.75	0.17	3.38	1.38	19.68	80.32
Lobster	14.49	1.84	...	1.71		
Lobster (canned)	18.13	1.07	...	2.47		
Crab	16.64	1.96	...	3.13		
Crab (canned)	15.80	1.55	...	1.94		
Shrimps (canned)	25.38	1.00	...	2.58		
Terrapin	21.23	3.47	...	1.02		
Green turtle	19.84	0.53	...	1.20		

Meat and Fish and Parasitic Disease.

Man is often the host of parasites through ingestion of infested meat and fish. Of these, the most common is the **tapeworm**, of which at least ten species are known, though only three have been demonstrated as having any connection with food. These are Tænia saginata (T. mediocanellata) due to measly beef, Tænia solium to measly pork, and Bothriocephalus latus to infested sturgeon, pike, perch, and salmon. The latter is very rare in this country, though not uncommon along the Baltic. Of the large number of worms which infest fish, this is the only one known to be conveyed to man. It is killed very quickly if the fish is cooked properly.

The larval forms of T. saginata and T. solium exist in beef and pork respectively as Cysticercus bovis and C. cellulosæ. The latter is found rarely also in mutton. Meats infested with these forms are

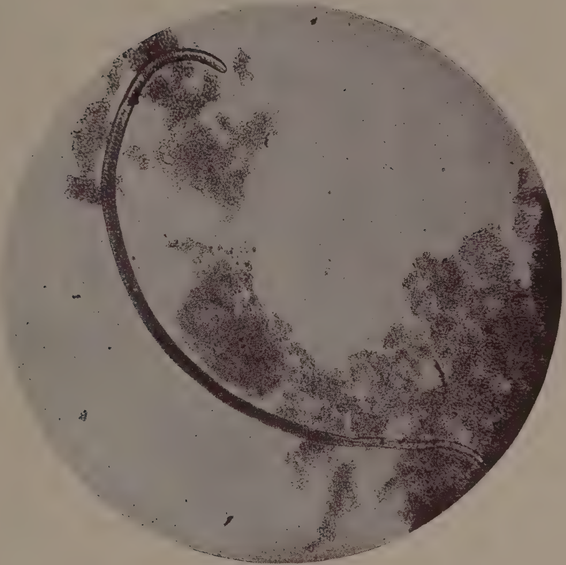
known as "measly" or "measled," and the animals from which the meats are derived are known as the intermediate hosts, man being the final host. The life history of the tapeworm is much more simple than that of many other parasites. Beginning with the adult tapeworm in man, the cycle is as follows: From each individual segment, which is possessed of a complete reproductive system, great numbers of eggs are discharged. The latter are expelled from the intestine with the feces, and some of them eventually may enter the digestive tract of cattle or swine through the food or water. In the intestine, the embryos become liberated from the eggs, and they then make their way in large numbers to the muscular tissues, brain, liver, and other parts, where they come to rest and develop as bladder worms. The bladders are variable in size, the smallest being about $\frac{1}{25}$ inch, and the largest about $\frac{3}{4}$ inch across, and, in the flesh, are embedded between the muscular fibers. The living animal shows nothing in its appearance to indicate the presence of the parasite, excepting when the cyst can be seen in the under side of the tongue or between the tongue and the lower jaw. If now the animal is slaughtered and the meat is eaten raw or imperfectly cooked, the Cysticercus is freed from its enveloping capsule and proceeds to develop into an adult tapeworm, and the cycle is complete. The Cysticercus bovis dies within two or three weeks after the slaughter of its host, and, therefore, measled beef, kept for three weeks in cold storage, becomes incapable of producing harmful effects. It is killed within 24 hours by pickling solutions of common salt, when brought into intimate contact. The Cysticercus cellulosæ lives rather longer in cold storage: probably a month or more, Both of these larvæ are killed by exposure to a temperature of 140° F. for 5 minutes, and as this is lower than the temperature in the interior of well-cooked meat, it is necessary only to make sure that the meat is properly cooked to escape danger. Neither parasite is destroyed by ordinary smoking or salting, but both are killed by hot smoking.

The sale of measled meat is permitted in many countries of Europe, but it must be sold as such and only in specially designated places. It finds a ready market at a low price, and the purchasers are warned that it should be cooked thoroughly. According to Virchow, since the introduction of systematic meat inspection, the proportion of tapeworm in the human subject dissected in Berlin has fallen from 1 in 31 to 1 in 280.

A parasite of far greater importance is the **Trichina spiralis**, which is found almost exclusively in pork and only occasionally in the flesh of other mammals and of birds and frogs. Trichinæ are small, thread-like worms, much longer than one would suppose on passing examination of fairly thick microscopic preparations, since they are coiled with several turns within the minute cysts in which they are lodged. In Plate I., Fig. 1, is shown one of the parasites in the free state. In the pig the worm infests both the fat and the voluntary muscles, but chiefly the latter, and especially the diaphragm, the intercostals, and the muscles of the jaw. When encapsulated in the flesh, their location may be

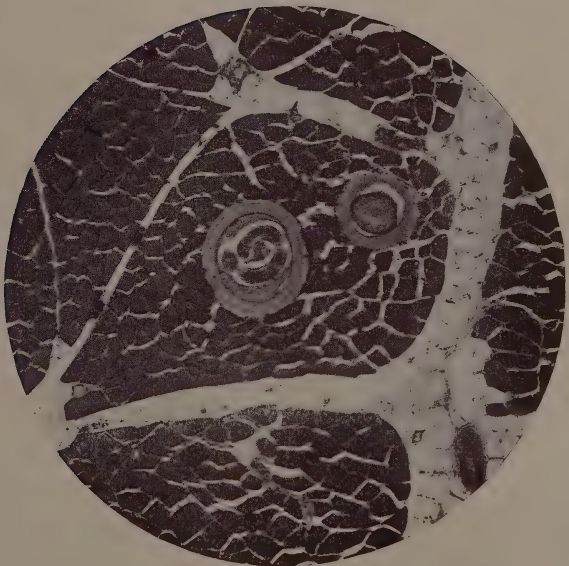
PLATE I.

FIG. 1.



Free Trichina. × 38.

FIG. 2.



Trichinæ in Human Muscle. × 75.

evident to the naked eye as small white specks. Thin sections of muscles, treated a few minutes in weak caustic potash solution (1 : 10), are soon made sufficiently clear to reveal the coiled worm under a lens of low power. If very much fat is present or if the capsule has become calcareous and thick, it may be necessary to employ ether or acetic acid before applying the potash. When the parasites are very numerous, the flesh is both speckled and pale.

Our first knowledge of the serious effects which may result from eating infested pork dates back only to 1860, although the parasite had been discovered in the muscles of a human subject by James Paget in 1833 and named by Richard Owen. It long was regarded as a harmless parasite and curiosity, and its effects were mistaken for rheumatism, typhoid fever, and other diseases of common occurrence. The case which finally revealed its capacity for harm was that of a young woman admitted to the hospital at Dresden suffering, it was supposed, from typhoid fever. In a short time, a train of symptoms quite unlike those of that disease appeared, the most marked one being very acute pain involving the entire muscular system, and intensified on attempting to move. On account of the agony induced, extension of the arms and legs was quite impossible. Pneumonia supervened, and in a few days the victim died. The autopsy revealed the parasite in vast numbers in the muscles, and this led to further investigation, which showed that, four days before the first symptoms of illness appeared, she had eaten freshly killed pork. Some of this was secured in the form of ham and sausage, and examination demonstrated the presence of the parasite.

The first extensive outbreak which caused the disease to be looked upon as one of great importance occurred in Prussia in 1863, when more than 20 persons died within a month after a dinner in which 103 had participated, and at which smoked sausages made from an infested pig had been served. The parasites were discovered in the muscles of those who died and in the sausages that remained. Since that time, it has been customary in most large slaughtering establishments to examine pork for evidence of the parasite, before passing it as fit for food. But examination is not always a safeguard, even in countries where it is observed most carefully. In Germany, for instance, where all meats are supposed to be examined with scrupulous care, particularly those from the United States, the disease is very common.

In 1883, on account of the alleged dangers which lurked in American meats, importation was interdicted for a time, but in the succeeding 15 years there were in Prussia alone 3,003 cases and 207 deaths, not one of which could be traced to American meat either salted, pickled, canned, or made into smoked sausages. Over 40 per cent. of the cases were traced to European meat which had been passed as free from trichinæ, and the rest to European meat which had been found to contain the parasite, but had, nevertheless, been handled by the trade. During 1899, the parasites were found by the microscopists of the U. S. Department of Agriculture in 41,659 of the 2,227,740 hogs examined.

It is probable, as stated by Charles W. Stiles,[1] who collected about 900 reported cases which had occurred in this country during the 36 years 1860–1895, that the disease is more common in the United States than generally is supposed. It is accepted commonly that 1 or 2 per cent. of dissecting-room subjects show evidence of the parasite, but it would appear from the investigations of H. U. Williams [2] that this estimate is much too low, for careful examination of 505 cadavers taken at random showed old encapsulation and calcification in no less than 27 instances, or 5.34 per cent. The birthplaces of the subjects included all of the most important countries of Europe and North America, but the number of cases examined was too small to admit of accurate conclusions as to the influence of nationality upon the frequency of the disease. It is evident that many cases of trichinosis escape detection, and that, as Williams points out, estimates have been based on naked-eye diagnosis.

In spite of the danger of eating trichinous meat, there are those who are not deterred by fear from eating it. In Germany, for instance, it has happened a number of times that hogs which have been condemned and ordered buried by the sanitary authorities have been dug up surreptitiously and eaten.[3]

Trichinosis bears certain resemblances to typhoid fever and to acute tuberculosis, but in addition is accompanied by œdema and intense pain. It arises from eating the infested meat in a raw or not well cooked condition. The trichinæ are killed by exposure to 155° F., if they are not encapsulated; otherwise by a temperature of 158° to 160°. They are not affected by intense cold, putrefactive processes, nor ordinary smoking, but are killed by long pickling.

The first symptoms appear in a few days after ingestion, and indicate irritation of the alimentary canal. These are followed by febrile symptoms and intense muscular pains. Death may occur within a few weeks. In case of recovery, the parasites become encysted, and then are incapable of producing further injury to their host. The manner in which they produce their effects is as follows: When the infested meat reaches the stomach, the digestive juices dissolve the capsules, and the parasites thus are left in a free state. In the intestine, they find conditions favorable to growth, and in a few days' time they grow so large that they can be seen with the naked eye and appear like fine threads.

The female parasites when fully mature begin to produce young, each to the extent of upward of 500. These begin at once a migration through the walls of the intestine and find their way to all parts of the body, and it is during this stage that the fever and intense pain are caused.

In Plate I., Fig. 2, and Plate II., Fig. 1, are seen thin sections of muscle from a human subject, showing the worm coiled up and the

[1] Philadelphia Medical Journal, June 1, 1901.

[2] Journal of Medical Research, July, 1901, p. 64.

[3] For an account of such a case consult Zeitschrift für Fleisch- und Milchhygiene, 1897, VII., p. 104.

PLATE II.

FIG. 1.

Trichinæ in Human Muscle, showing Thickened Capsule. × 75.

FIG. 2.

Trichinæ in Pig Muscle. × 75.

thickened capsule formed about it. In Plate II., Fig. 2, it may be seen within the muscle of an infested pig.

The sheep disease which is known as **rot**, which term, it must be said, is used to include a large number of abnormal conditions, but which, in its strict application, means a parasitic disease of the liver, is believed by many to be of sufficient importance to warrant the condemnation of the flesh of the animal, but the scientific evidence on this point is to the effect that no possible harm can come to the consumer, even though the liver itself be eaten. The parasite infests not alone sheep, but cattle as well, and is known as the "fluke." Of the many varieties of flukes, there are but two known in the United States; these are the common liver fluke (leberwurm, leberegel, schafegel, douve hépatique) and the large American fluke. The former infests cattle and sheep; the latter, only cattle.

The life history of the worm is exceedingly complicated, and is as follows: The adult or hermaphroditic worm fertilizes itself in the biliary passages of the liver, and produces an exceedingly large number of eggs, which pass to the intestine of the host with the bile, and are expelled in the feces. Such of the eggs as eventually reach water give rise after a longer or shorter period, according to temperature, to a ciliated embryo, which on its escape from the egg becomes a free swimming ciliated miracidium, and enters the body of certain species of snails, where it comes to rest. Here the organism grows, and, after a time, certain germ cells in its posterior portion develop a still different form of life, the ridiæ. These wander to the host's liver and increase in size, and in turn develop from their germ cells the next generation, which are called cercariæ. These leave the body of the snail and swim about in the water, and some become attached to blades of grass, where they form enveloping cysts and undergo anatomical changes. For their next stage it is necessary that they be received into the stomach of some herbivorous animal by being swallowed with the grass to which they are attached. On reaching the stomach, the cysts are destroyed and the parasites migrate to the liver and become adult hermaphrodites, thus completing the cycle. Occasionally they wander to the lungs and other parts of the body. In the liver, the parasites attach themselves to the walls of the bile ducts, which may become completely blocked, and they cause the breaking-down of the surrounding tissues and general symptoms due to structural changes. The parasite cannot be transmitted directly from animal to man, since it requires an intermediate host, and in the stage preceding its final development it is not attached to material constituting human food. There are, to be sure, some instances of the disease in man, though not by direct transmission from meat. The condition caused by flukes is known variously as rot, liver rot, fluke disease, and distomatosis.

TRANSMISSION OF DISEASE BY MEAT AND FISH.

Living pathogenic bacteria in diseased meat and fish may gain access to the stomach in limited numbers and beget no disease. If they are not destroyed by the gastric juice, they have to contend with myriads of organisms normal to the intestines, and it is only when the conditions are such as to favor extensive multiplication that they are likely to produce harmful effects. In meat that is cooked thoroughly, they are killed by the heat to which they are subjected.

It is well known that the stomach has great protective power in its natural functions, since certain violent organic poisons may be taken into that organ without injury, while if the same are introduced into the circulation, the results are fatal; thus the venom of poisonous serpents is digested and made harmless by the stomach juices. An instance of the immunity conferred by cooking or by the process of digestion, or by both together, and of the fatal result of the admission of the harmful element of the same meat to the system through cuts and abrasions, is given by Lardier.[1] The case is as follows:

A cow died suddenly of anthrax and was dressed for food. The meat was eaten by a large number of people, none of whom suffered the slightest inconvenience or injury. A number of cats, however, which ate some of the waste matters and licked up the blood, died with some suddenness. A woman who bought the head and wounded herself in the process of cutting it up had a charbon at the place of injury and died. Two men who helped skin the cow had charbon, but recovered. A calf belonging to one of these two died of anthrax, and another man, removing the skin, cut himself and died. The skin of the original animal was sold and the purchaser put it in a shed on his farm. Some time later, one of his cows died suddenly, and the man who dressed the carcass wounded himself during the process, acquired a charbon, and died. How much farther this series of fatalities might have extended cannot be known, since the authorities took steps in the matter and prevented further fatalities.

Many instances are known in which the flesh of cattle dead of infectious disease has been eaten with impunity. During the siege of Paris, for example, when the food supply was exceedingly limited in amount, no one paid the slightest attention to the condition of meat in respect to disease, even glandered horses finding a ready market, and, so far as is known, no ill effects resulted.

Many years ago, when the *rinderpest* was very prevalent in Bohemia, the diseased cattle were killed and buried by order of the government; but the poorer class dug up the carcasses and cooked and ate them without suffering any evil consequences whatsoever.

During the prevalence of the same disease in England in the early sixties, the meat from the diseased animals in all stages of the distemper was sent in enormous quantities to market, and sold and eaten without evil effects. A similar immunity has often been noticed after

[1] Revue d'Hygiène, 1898, No. 5, p. 431.

the consumption of the carcasses of animals dying from acute *pleuro-pneumonia*. In ordinary cases of this disease, which is peculiar to beef cattle, the effects are localized in the lungs. Sometimes, in very pronounced cases, the flesh is altered in appearance, becoming dark and discolored, and it is also moist and flabby. It is believed that the meat is edible, if it possesses a normal appearance. The meat in rinderpest undergoes no marked change in appearance, excepting in advanced cases, when it is dark in color and flabby and of disagreeable odor.

In ordinary cases of *foot and mouth disease*, it appears that the carcass is edible, but in exceptional cases, when the animal has suffered for a long time, the flesh may be so deteriorated as to be undesirable. As a rule, although the disease is very infectious, its course is mild and interferes only slightly, if at all, with the condition of the meat, which generally cannot be distinguished from that of healthy animals.

Although many instances are known that show that the meat of animals suffering with *anthrax* may be eaten without injury, it is the unanimous opinion of those who have given the matter attention, that, no matter how good the meat may appear, it should be condemned and destroyed. If the meat is well cooked, accidents are rare, but many cases of fatal injury, involving a large number of victims, have been traced to the use of such meat, presumably not thoroughly cooked. In spite of the protection conferred by cooking, there is such an element of danger, even in the handling of the meat, that its use should be discouraged and forbidden. In Scotland, it is a common practice with farm laborers and other poor to eat the meat of sheep which have died of acute inflammatory diseases, even of *anthrax*. The carcass of an animal dying of disease is the perquisite of the herdsman and almost invariably is eaten after being salted. No precaution is taken, except to cut away the darker portions of the meat which show stagnation of the blood. Occasionally, serious consequences, due either to imperfect cooking or to insufficient salting, result from its consumption.

It is held generally that the flesh of animals that have died from *actinomycosis*, *puerperal fever*, "*strangles*," *hog cholera*, and *sheep scab* is unfit for human food.

Tuberculosis.—The cattle disease most commonly known in this country, if not elsewhere, is *tuberculosis*, and concerning the advisability of using the flesh of its victims, there is much difference of opinion, here and abroad. The disease is more common in cows, especially those kept in confinement, than in steers and oxen. It is almost an unknown disease in the great herds roaming the western plains. In Berlin, in 1892–93, 15.1 per cent. of all cattle, 1.55 per cent. of swine, 0.11 per cent. of calves, and 0.004 per cent. of sheep slaughtered showed some evidence of the existence of the disease. In Copenhagen, in the years 1890–93, the figures were somewhat higher than those of Berlin, excepting in the case of sheep. They were as follows: 17.7 per cent. of cattle, 15.3 per cent. of swine, 0.2 per cent. of calves, and only one sheep out of 337,014. At the abattoirs of Leipzig, in 1897, nearly

half of the cows and about 20 per cent. of the other cattle were found to be tuberculous; 2.78 per cent. of swine, 0.2 per cent. of calves, and 8 sheep out of 49,559.

Out of over 8,000 beeves of American origin landed, slaughtered, and examined at Hamburg, 4 were found to be tuberculous, while of the same number of native animals, 640, or 160 times as many, were found to be afflicted with the disease. At that time the German press had been carrying on one of its periodical agitations against the importation of American beef cattle on account of the dangers to which native breeds were thereby subjected.

In Great Britain, 30 per cent. of the cows are estimated by MacFaydean to be tuberculous. In Belgium, of 20,850 animals tested with tuberculin in 1896, 48.88 per cent. reacted. In Denmark, of 67,263 thus tested, 32.80 per cent. reacted. In Mexico, about a third of the beeves slaughtered are tuberculous.

In this country, while the percentage of affected animals is low, it is believed to be on the increase, both with cattle and swine. In the State of New York, it is said by veterinarians that, in some districts in which the herds are mainly of the hardy grades of the Ayrshire, Holstein, and Short-horn families, about 1 per cent. of the cows, and in others where Jerseys and Guernseys are more common, about 2 to 3 per cent. are tuberculous. In Massachusetts, those in a position to be best informed state that, among cows, the disease is much more frequent than in New York, but that it is rarely to be found in calves, steers, and oxen. In Pennsylvania, the State veterinarian believes that not over 2 per cent. of all cattle are tuberculous. At the large abattoirs of this country, about 1 in 2,000 cattle is found to be tuberculous. During the two years ended June 30, 1899, 8,831,927 cattle were inspected by the Federal authorities, and 7,015, or 1 in 1,259, were condemned on account of tuberculosis. During 1900, of 4,861,166 inspected, 5,279, or 1 in 921, were condemned. Of 23,336,884 hogs inspected, 5,440, or 1 in 4,290 were sufficiently affected to warrant condemnation of at least a part of the carcass.

The organs involved most frequently in tuberculosis of animals are the liver, lungs, kidneys, brain, and udder. The muscles are affected very rarely, although the bacilli have been found in the expressed juice.

At what stage of the disease meat becomes unfit for food, is a question over which there is much controversy. Extremists on the one side believe in condemning the entire carcass on the slightest evidence of disease in any part thereof, while those on the other side maintain that the entire animal may be used as food without injury. In England, the practice is to condemn any carcass in which the disease has made such extensive progress that the flesh has become deteriorated. The Royal Commission on Tuberculosis[1] concluded that meat from tuberculous animals may be consumed with impunity, if sufficient discrimination and care are exercised in slaughtering and dressing. Every part containing tubercles should be removed and

[1] The Veterinary Journal and Annals of Comparative Pathology, June, 1895.

destroyed, and the whole carcass itself in advanced or general tuberculosis.

The French law excludes carcasses with generalized tuberculosis and those in which local lesions have involved the greater part of an organ. The same is true in Austria. In Prussia, the meat is held to be unfit for food if the animal has begun to show emaciation, but is passed as fit for human consumption if the disease occurs in only one organ, and in general, if the animal is well nourished. In Belgium, the law of September 30, 1895, permits the sale of meat of tuberculous animals after sterilization.

Meat from tuberculous cattle is infective to other animals in very variable degrees. As a rule, the more advanced the disease, the more likely is the meat to be infective. Experiment has demonstrated that infection depends to a not inconsiderable extent upon contamination of the meat, in the process of dressing, by the hands, knives, or cloths, which have been in contact with tuberculous matter.

Although lesions in the muscular tissue itself are not at all common, positive results have repeatedly been obtained in experiments in which the expressed juice of the meat has been injected into susceptible animals. Thus, Kastner obtained 9 positive results in 11 injections of the juice of the meat of 7 tuberculous animals, and Steinheil transmitted the disease to guinea-pigs by means of juice from meat apparently sound. Arloing inoculated the muscle juice of 10 tuberculous cows into guinea-pigs and demonstrated that that from 2 of the animals was infective. Nocard produced the disease with the muscle juice of but 1 of 21 tuberculous cows with which he experimented. All of these cows had been condemned at the abattoir on account of extensive lesions. Woodhead, Galtier, Humbert, and others have met with varying degrees of success in similar experiments.

That tuberculosis can be transmitted to animals by feeding them on tuberculous material has been abundantly proved, but the lesions produced almost never involve the muscular apparatus, and many of the subjects escape infection altogether. It was reported, for example, by Thomassen, at the Tuberculosis Congress at Paris, that of 10 young pigs, each of which was made to eat 4.5 kilos of meat from animals with advanced general tuberculosis, but 2 were affected, and their portions had contained a quantity of splintered bone. Ravenel[1] has held for a long time that food tuberculosis may appear first in the lungs and cervical glands, and cites the case of 2 cows which, fed on tuberculous material, developed extensive disease of the lungs and lesions nowhere else. As stated by Dr. D. E. Salmon,[2] Woodhead, St. Clair Thompson, and Lord Lister have shown "that infection through the medium of the food may not necessarily be accompanied by disease of the intestines. The organs first attacked after feeding on tubercular material may be the mesenteric glands and liver, or even the bronchial and mediastinal glands and the lungs."

[1] Philadelphia Medical Journal, August 14, 1901, p. 284.
[2] Bulletin No. 33, Bureau of Animal Industry, Washington, 1901.

The question of the identity of the bacilli of human and bovine tuberculosis, raised in 1901 by Koch's assertion of the impossibility of transference of the disease from man to cattle and from cattle to man, has led to much experimentation and study, and although there is as yet no general agreement in the interpretation of the results obtained, the weight of evidence appears to favor the contention that the two diseases are one and the same, although reciprocal transmissibility is opposed by systemic differences. The respective organisms differ in virulence, morphology, and cultural peculiarities, but so do different strains of the same variety. Ravenel[1] believes that the bovine bacillus shows persistent peculiarities of growth and morphology, which enable it to be differentiated from the human variety, and that it is much more pathogenic, not only for nearly all of the species of experimental animals, but for man also. He says,[2] moreover, that human bacilli with a high degree of virulence for experimental animals are rarely found, and that cultures highly pathogenic for cattle are still more rare. That the bovine bacilli are more dangerous to man than the human variety, is the conclusion drawn also by Fibiger[3] from a review of recent work on the communicability of human tuberculosis to cattle. Experiments conducted by Nocard, Cipollina, and others indicate that the bovine bacillus is the more infective. Nocard[4] observed that monkeys fed with material containing bovine bacilli became infected much sooner than did those whose food contained the human variety; and Cipollina[5] produced general tuberculosis in a healthy ape with milk containing bovine bacilli, while a calf resisted infection with the human variety. In Ravenel's experiments, guinea-pigs infected with human bacilli lived more than twice as long as those inoculated with the bovine variety, and rabbits were much less extensively infected and, indeed, gained in weight.

That human bacilli from different lesions are differently virulent, has been observed repeatedly. Those from the lungs almost invariably fail to infect calves, but Fibiger and Jensen[6] found that bacilli from 3 cases of chronic intestinal tuberculosis were exceedingly virulent, and Wolff[7] produced general tuberculosis in a calf which he inoculated with material from a similar source. Ravenel[8] also has found two cultures from the mesenteric glands of milk-fed children, one quite as virulent as bovine bacilli, and the other more potent than the usual human culture. Orth[9] has convinced himself by experiment and observation that human and bovine tuberculosis are reciprocally transmissible, and he believes that virulence can be increased materially by passage through

[1] Journal of Comparative Medicine and Veterinary Archives, 1902, pp. 65, 139.
[2] Journal of the American Medical Association, June 3, 1903.
[3] Hospitalstidende, XLVI., Nos. 9 and 10.
[4] Journal of the Sanitary Institute, January, 1903, p. 571.
[5] Berliner klinische Wochenschrift, February 23, 1903, p. 163.
[6] Ibidem, September 22, 1902.
[7] Ibidem, November 17, 1902.
[8] Journal of the American Medical Association, June 3, 1903.
[9] Berliner klinische Wochenschrift, July 20, 1903.

a series of animals. Behring[1] increased the virulence of the human bacillus by passage through rabbits and goats, until it became as virulent for cattle as any strain of bovine bacilli; and, according to Salmon,[2] Mohler did the same by passage through five cats. Hamilton and Young[3] noted an enormous increase in virulence on reinoculation from one calf to another and great variation in morphological character. Arloing reports positive results from inoculation of cattle, asses, sheep, and hogs with human bacilli from five sources, and Theobald Smith has found a human culture directly virulent for cattle.

Raw,[4] who, during the past few years has had more than 3000 cases of pulmonary tuberculosis under observation, inclines to the belief that man is subject to two kinds of tuberculosis: the pulmonary form, rare in children under 12, and due to human bacilli, and other forms, as tubercular joints, tubercular meningitis, and abdominal tuberculosis, rare in adults and due to bovine bacilli. In a period of 12 years he saw nearly 300 cases of tabes mesenterica, and not one of the subjects was a breast-fed child. Von Hansemann[5] gives the particulars of 25 cases of intestinal tuberculosis due apparently to bovine bacilli. He believes that infection can take place through the healthy mucous membrane, and von Behring[6] is of like mind. He believes that the chief source of tuberculosis is infected milk, and that infection of infants is due to lack of continuity of the epithelial lining of the alimentary tract, which permits the passage of bacteria.

Evidence that infection of the lungs can occur through food without local lesions of the digestive tract is offered by several. Thus, Nicolas and Descas[7] fed fatty broth containing large numbers of tubercle bacilli to healthy dogs, some of which, after three hours, yielded chyle containing bacilli in such abundance that they could be demonstrated microscopically; and Ravenel[8] introduced a quantity of bovine bacilli in melted butter into the stomachs of 8 healthy fasting dogs, and found that the chyle and mesenteric glands, removed about 4 hours later, were infective for guinea-pigs, and that not the slightest evidence of abnormality of the intestinal mucosa could be seen. MacFadyen[9] obtained like results with monkeys fed with tuberculous material from cattle. General tuberculosis was produced, but no lesions of the intestines were observed.

The German Tuberculosis Commission, appointed on Koch's suggestion, found that different bovine cultures varied much in virulence, some failing to transmit the disease to other cattle. They tested 39 cultures of human origin and found 4 that caused general tuberculosis

[1] Beiträge zur Exper. Therapie, No. 2.
[2] Journal of the American Medical Association, March 12, 1904.
[3] Public Health, September, 1903, p. 689.
[4] British Medical Journal, October 8, 1904.
[5] Berliner klinische Wochenschrift, 1903, No. 7, p. 141, and No. 8, p. 170.
[6] Deutsche medicinische Wochenschrift, 1903, No. 39.
[7] Centralblatt für Bakteriologie, etc., 1902, XXXII., p. 306.
[8] Journal of Medical Research, December, 1903, p. 460.
[9] The Lancet, September 12, 1903.

in calves. Thus, both kinds differ in virulence. But the four that proved virulent for calves were derived from children, and Kossel[1] concludes that the children must have been infected by bovine bacilli. His experiments show that bovines, in a certain small proportion of cases, may yield to human bacilli, and in endeavoring to explain the fact, he admits that the reverse is also true. Orth,[2] having succeeded in producing general tuberculosis in 2 out of 5 calves inoculated with human bacilli, asks Koch to reconcile his own negative results with the positive results of others.

Of very great importance is the interim report of the Royal Commission, appointed in 1901 to inquire into the relations of human and animal tuberculosis, which concludes[3] that the two are identical, both in general features and in finer histological details. More than 20 strains of human tuberculous material—from lungs, sputum, glands, and joints—were employed, and 7 of them were found to be capable of causing acute tuberculosis in cattle, with lesions in various organs (lungs, spleen, liver, lymphatic glands, etc.). "In some instances the disease was of remarkable severity." Several of the less virulent strains were found to gain greatly on reinoculation from one bovine into another or into a guinea-pig.

Concerning the possibility of direct transmission of tuberculosis from animal to man by inoculation, considerable evidence is offered, but in most cases the infection is local and is due to wounds received in making autopsies on diseased cattle. Pfeiffer[4] records an accident of this sort which was followed in 18 months by death from phthisis, and the originally infected joint was found to be extensively tubercular. Spronck and Hoefnagel[5] record a similar case. A man aged 63 years cut his finger while skinning a very tuberculous cow, and, though the wound healed quickly, the glands at the elbow became enlarged and, after nine months, they were excised and found to be infective for guinea-pigs. The disease was conveyed from one of these to a healthy heifer, which showed general infection after two months. The man developed a catarrh of the right apex 20 months later. Lassar[6] has seen in ten years 34 cases of undoubted inoculation tuberculosis, chiefly in veterinarians, butchers, and others who handle meats.

The fact that so few cases of infection occur among the army of men who are constantly exposed to the possibility of wounds during slaughtering leads Flick[7] to conclude that bovine tuberculosis is only slightly virulent for man, and that it is not right to declare meat and milk from tuberculous animals dangerous to man.

Concerning the possibility of transmission of tuberculosis by eating the meat of diseased animals, there is practically no evidence of value,

[1] Berliner klinische Wochenschrift, July 20, 1903.
[2] Ibidem.
[3] Interim Report, London, 1904.
[4] Zeitschrift für Hygiene, III., p. 209.
[5] La Semaine Médicale, October 15, 1902, p. 341.
[6] Deutsche medicinische Wochenschrift, October 2, 1901.
[7] Journal of Tuberculosis, 1902, II., No. 4.

but whatever danger there is, if any at all, is disposed of by thorough cooking, since thereby the bacillus is quickly killed. Since raw meat is frequently used as food, particularly in some diseased conditions, it is best, in order to be on the safe side, to see that meat so used shall be free from infective properties.

Typhoid Fever and Cholera.—Foods of all kind may be made the bearers of infection to man, though themselves in good condition. Particularly is this noticeable with regard to oysters, which have many times conveyed the specific organisms of typhoid fever and cholera.

In 1880, Sir Charles Cameron[1] brought to the attention of the profession, that oysters, transplanted from the coast of the County of Wexford to the northern shore of Dublin Bay, had for some years been much subject to disease and had died in large numbers. Specimens which were examined were found to contain sewage matters, and investigation showed that the beds "were literally bathed in sewage." He offered the suggestion that raw oysters, taken from the shore close to sewer outlets, were, perhaps, as likely to act as the vehicle of typhoid fever and other diseases as contaminated water or milk, and advised that "oyster beds should not be laid down at any point on or close to the mouth of a sewer." But the warning appears to have excited no more than a languid interest until 1893, when the late Sir R. Thorne-Thorne, in a report to the Local Government Board, stated his belief that the sporadic cases of cholera which had occurred at various inland places in England in that year were due to oysters and other shellfish from sewage-contaminated water at Grimsby, where there had been a small outbreak of the disease.

In the following year occurred the well-known outbreak of typhoid fever at Wesleyan University, which was so ably and conclusively traced by Professor Conn[2] of that institution to polluted oysters. On October 20, 1894, several of the students were reported as slightly ill, with a moderate degree of fever. The number of cases grew from day to day, and shortly included several of undoubted typhoid fever. By November 1st, there were 20 cases of the disease, which number was shortly further increased to 23. All of the victims were men; there was no illness among the 58 women students. Investigation completely absolved the water supply, the general and particular food supplies of the various boarding places, and the local conditions of the dormitories and outside lodgings of all suspicion of blame. It appeared that nearly all of the victims were members of three of the seven college fraternities. The combined membership of the three was about one hundred. On October 12th, eight days before the development of the first symptoms, all seven fraternities had had their initiation ceremonies and had celebrated in the usual way with a supper. Investigation of the origin of the components of the suppers showed that there was but one dish from a common source, and that was oysters. The three afflicted societies and one other had obtained

[1] British Medical Journal, September 18, 1880, p. 471.
[2] Medical Record, Dec. 15, 1894, p. 743.

their oysters from a local dealer; of the remaining three, two had had no oysters, and the third had had some from a dealer in Hartford. Of the four supplied by the local dealer, one had eaten the oysters cooked, and its membership was not invaded. Thus the trouble was sifted down to the raw oysters from the local dealer. But there was one victim who was a non-society man, and, clearly, his case could not be traced to the initiation supper. Investigation of his dietetic history established the guilt of the local oyster supply even more securely, for it was shown that he had eaten raw oysters from the same lot at the shop of the dealer. It was learned, too, that 5 men from Yale had attended the exercises of the societies in which the outbreak occurred, and inquiry developed the information that 2 of the 5 were seized with typhoid fever some weeks after their return to New Haven. Further investigation revealed the fact that the incriminated oysters had been brought from a bed in Long Island Sound, and, on October 10th, two days before use, had been stored in a bed at the mouth of the Quinnipiac River, a short distance (300 feet) from the outlet of a private drain from a dwelling, in which 2 persons lay ill with typhoid fever.

Dr. Arthur Newsholme,[1] M. O. H. for Brighton, England, reported that of 53 cases of typhoid fever occurring within his district during 1894, no fewer than 15 were due to infected oysters, and 6 to other contaminated shellfish (clams, cockles, and mussels). In a later communication,[2] after a thorough examination of the cases that had occurred within four years, he reported the percentages of infection due to oysters and mussels as follows: In 1894, 38.2; 1895, 33.9; 1896, 31.8; 1897, 30.7.

Dr. J. T. C. Nash,[3] M. O. H. for Southend-on-Sea, says that prior to 1900 attacks of typhoid fever within his district were ascribed to the commonly accepted causes and occasionally to shellfish. In 1900, investigation showed that in a majority of the reported cases there was a history of consumption of shellfish within 2 or 3 weeks of the onset. In a majority of the cases reported during the last 5 months of 1901 there was a similar history. During June and July, 1902, in a majority of the 39 cases reported there was a history of eating, within a month of the onset, cockles from a sewage-polluted creek in another district, where, during June, 9 cases of typhoid fever had existed. Cockles obtained from these layings were examined and the presence of sewage bacteria was demonstrated. In a later communication [4] he states that in 82 of the 102 cases of typhoid fever reported during 1902 there was a shellfish history. Diminished consumption of shellfish, the adoption of better methods of storage, and the exercise of greater care in obtaining supplies from clean layings were followed by a very decided diminution in the incidence of typhoid fever. By careful inquiry he determined that somewhat less than 5 per cent. of the

[1] British Medical Journal, June 8, 1905, p. 1285.
[2] Public Health, September, 1898.
[3] Journal of the Sanitary Institute, January, 1903, p. 369.
[4] Journal of State Medicine, December, 1903, p. 710.

entire population of the district were eaters of shellfish, and during 1902 the attack-rate of typhoid fever per 1000 among this section was 51.25 against 3.28 for the whole population, and 0.75 for the non-eaters of shellfish. The attack-rate among the dealers and their employees was no less than 160 per 1000.

Dr. J. F. Allen,[1] M. O. H. for Westminster, secured specimens of cockles which were from the same bed as some which were supposed to have caused a number of cases of typhoid fever, and had them examined, at the Jenner Institute, for sewage bacteria. The results were positive, and the typhoid bacillus itself was found to be present. Hewlett[2] records that cockles purchased at the fishmarket of Billingsgate and examined by Klein yielded the usual sewage bacteria and the typhoid organisms as well. Four cases of typhoid fever attributed to cockles from the same source were the cause of the inquiry. Sewage contamination was demonstrated by the same authority in 11 of 18 lots of oysters from five different localities.

Chantemesse[3] relates the following case: There had been no case of typhoid fever in the village of l'Herault Saint André de Sangonis for about a year, when, on February 15th, a shopkeeper received a consignment of oysters from Cette. The entire lot was consumed by 14 persons, all of whom were made sick. In the 6 dwellings in which the victims lived, no other inmates were sick in any way. Eight of the number were made only slightly ill, the symptoms, which included abdominal pain, vomiting, diarrhœa, borborygmus, anorexia, and general malaise, lasting but 2 or 3 days. The 4 youngest, who ate but a few, were very sick for a much longer time (15 to 25 days), but recovered. The stools were very offensive, were passed with pain, and were dysenteric in appearance; there was tympanites with tenderness and gurgling. All 4 were greatly prostrated. The remaining 2, a woman of twenty and a man of twenty-one, developed very severe cases of typhoid fever. The woman died.

Mosny,[4] to whom the French authorities referred the whole subject of mollusk poisoning for investigation, has reported that 5 members of a family of 7, living in a village in a suburb of Paris, in which there had been no case of typhoid fever in 4 years, were made sick after eating oysters sent to them from Cette. Four were seized in the evening of the following day with gastro-intestinal disturbance, which lasted 24 hours. On the eighteenth day, a youth of 17 years developed unmistakable symptoms of typhoid fever, of which, 9 days later, he died. In March, 1897, Chatin[5] reported the case of a family, of which several members were stricken with typhoid fever after eating oysters from a bed which was contaminated by sewage.

Klein and Boyce have shown that oysters contaminated by typhoid

[1] Journal of the Sanitary Institute, January, 1903.
[2] Journal of State Medicine, March, 1903, p. 163.
[3] Bulletin de l'Academie de Médecine, 1896, 35–36, p. 588.
[4] Revue d'Hygiène, January, February, and March, 1900.
[5] La Semaine Médicale, 1897, p. 9.

bacilli can retain their infective properties for 2 or 3 weeks, and it is shown that those from sewage-contaminated beds may not be eaten with entire safety until they have lain for about 2 weeks in unpolluted water. It appears, however, that in cockles the typhoid organism thrives, and that this kind of shellfish is not freed of its infective properties by storage in clean water. Although cockles are not eaten raw, the cooking to which they are subjected is by no means thorough, for boiling for any considerable time makes them tough and uneatable.

It was shown by Foote,[1] after the outbreak at Wesleyan University, that typhoid cultures, introduced within the cells of oysters from the bed from which the incriminated oysters were derived, were virulent at the end of 48 hours, which was the period which elapsed between the gathering and consumption of those which caused the outbreak. Furthermore, it was demonstrated that, if the specimens were kept at 57° F., the organisms were active as long as a month later.

The influence of the sewage of a large city is shown by C. A. Fuller,[2] who collected samples of water and shellfish from various places in Narragansett Bay, into which about 14,000,000 gallons of sewage from Providence, Rhode Island, are discharged daily. Water, oysters, clams, and mussels, taken at a distance of a quarter of a mile from the sewer outlet, yielded *Bacillus coli communis*, *Bacillus cloacæ*, and *Bacterium lactis aërogenes*. The water and oysters from a bed two miles distant yielded the same organisms. *Bacillus coli communis* was found in 30 per cent. of the oysters, and in 60 per cent. of the samples of water from a bed situated in the line of a strong tidal current, five miles away; and in 40 per cent. of the oysters and 70 per cent. of the water samples from another in sluggish water more than five miles away. One bed six miles distant was found to be contaminated, but those farther down than six and one-half miles were unpolluted.

These findings are in accord with the statement of Dr. E. Klein,[3] that the nearer to sewer outlets oysters and cockles are planted, the greater the percentage of specimens yielding evidence of pollution. In the examination of oysters he holds that the presence of *Bacillus enteritidis sporogenes* alone is not sufficient proof of recent sewage pollution, but that when the spores of this organism are found together with streptococci and *Bacillus coli communis* they constitute strong evidence of recent contamination.

Dr. Hibbert W. Hill[4] has recorded interesting results of examination of clams from flats in the immediate vicinity of the sewer outlets of a number of private dwellings. Attention was devoted solely to the bodies of the clams and not to the water contained between the shells, which was practically the same as that which surrounded them. The technique followed was such as to insure absolutely against contamina-

[1] Medical News, March 23, 1895.
[2] Science, 1902, No. 375, p. 363.
[3] British Medical Journal, February 21, 1903.
[4] Report of the Board of Health of Boston, Massachusetts, for 1901.

tion by bacteria on the surface, and the portion of the body selected as most likely to show infection was the intestines. The following were isolated and identified: *Bacillus coli communis*, *Bacillus enteritidis sporogenes*, and *Bacillus aërogenes capsulatus* (Welch), all three of which are found commonly in sewage. The typhoid bacillus was not found nor was it expected, since there was but 1 case in the neighborhood and the excreta were disinfected. Dr. Hill adds that the search for typhoid bacilli in sewage known to contain them is, in most cases, practically hopeless, since even in severe epidemics the number of typhoid patients contributing to the sewage is almost always small in comparison with the total contributing persons, and only a small proportion of the bacteria present in a typhoid stool are typhoid bacilli; and to hope to find, by examining a few cubic centimeters from a large mass of water, a bacillus which is present in the proportion of one to every ten or hundred gallons of water, is almost, if not quite, useless.

From a series of experiments undertaken to determine the question of viability of the typhoid organism in sea water and within the oyster, Bordoni-Uffreduzzi and Zernoni[1] concluded that it will live over 2 weeks in sea water and from 3 to 4 days in oysters, without lessening of virulence. Oysters from Spezia, Venice, and elsewhere, were examined to determine the presence of the typhoid organism in the water contained between the shells or in the tissues. The results were negative on this point, but the colon bacillus was isolated from oysters from 3 different sources. Oysters immersed in sterilized sea water, which later was infected with cultures of the typhoid organism, yielded virulent bacilli from the water between their shells up to the ninth day of examination, but never from the tissues themselves.

Other observers have found the bacteria of cholera and typhoid fever, *B. coli communis*, *B. proteus vulgaris*, and other organisms, in oysters contaminated by sewage, and all unite in the opinion that the presence of *B. coli communis* should arouse suspicion and induce improvements in the management and supervision of oyster beds.

In the investigation of outbreaks of typhoid fever supposedly due to oysters, bacteriological proof of specific infection of those eaten or of others from the same lot always has been and always will be wanting, since, long before the appearance of the first symptoms of the disease, the material is no longer available for investigation. But, in view of the fact that pathogenic bacteria have been found in the water between the shells of oysters from polluted beds; that they have been known to live for days in the tissues and retained water; and that, in the cases investigated, the beds have been found to be exposed to the influence of sewage, we may, therefore, properly conclude that a causal relation is very possible.

The danger of infection arises wholly from the presence of sewage in the water where the oysters are planted or stored. The remedy lies either in transferring the beds to cleaner situations or in storing the con-

[1] Giornale della Reale Società Italiana d'igiene, 1899, p 500.

taminated oysters in clean sea water until the bacteria either have perished or have been washed away. What constitutes a sufficient length of time to insure purification, is a matter of some disagreement. Many believe that a week is enough; others, that 16 days should be allowed. Oysters should not be stored where sewage matters can reach them through long distances by currents along the shore, nor where prevailing winds can exert a harmful influence to the same end.

Poisoning by Meat and Fish.

Animal foods are the frequent cause of most distressing disorders which not rarely have a fatal termination. Some of these are due to poisonous properties inherent in the living animal, some to bacterial poisons formed in meats showing no evidence of unwholesomeness, and some to decomposition products developed during storage or putrefaction.

1. **Poisoning Due to Substances Normally Present in the Living Organism.**—As has been stated, certain species of fish are always poisonous and others only at times, and in some cases only individual members are so constituted. Certain species are so well known to be poisonous in perfectly fresh condition that they never are eaten by the natives of the places where they are found, except for purposes of suicide. Some have poisonous glands connected with their fins, some have poisonous ovaries, and others are poisonous throughout. Some are poisonous only in the raw state, and others whether cooked or not. The symptoms produced vary widely, sometimes indicating gastro-enteritis, sometimes involvement of the central nervous system.

The mussel is regarded not uncommonly as an intrinsically poisonous shellfish, but the weight of evidence indicates that mussel-poisoning is due to conditions of disease or infection arising from residence in polluted water. Its poisonous properties have long been recognized, and have been the subject of a number of dissertations by early writers; thus Behrens, *De affectionibus a comestis mytulis*, Hannover, 1735, and Moehring, *Mytulorum quorundam venenum et ab eo natas papulas cuticulares Epistola*, Nuremberg, 1744. In France, where great quantities of mussels are eaten, cases of poisoning thereform are rare, owing doubtless to the fact that those taken from polluted harbors are kept for a week or more in clean water elsewhere.

2. **Poisoning Due to Bacterial Products in Meats and Fish.**—What is known commonly as meat-poisoning, fish-poisoning, and sausage-poisoning is due to the products of a number of micro-organisms having no connection with the usual diseases of man. These products, which include toxins and ptomains, cause an extremely wide variety of symptoms, which, as may be observed on examination of the collection of reported outbreaks given below, indicate the possible derangement of function of practically every part of the system. There are two groups of symptoms, however, which are fairly constant, either one of which may predominate over all the rest. These are (1) the manifes-

tations of profound disturbance of the gastro-intestinal canal, and (2) those indicating more or less intense poisoning of the central nervous system. Prominent among these latter are impaired vision (dilated pupils, ptosis, amphodiplopia, etc.), and glosso-pharyngeal paralysis; and when those are present, the case is said to be one of "botulism." This term, which came into existence by reason of the fact that many of the earlier observed cases of food-poisoning were traced to sausages (*botulus*, a sausage), is, in the light of our present knowledge, unfortunate and misleading, for the condition may be caused not only by sausage, but by any form of meat and fish which may happen to be contaminated by the micro-organisms which produce the peculiar toxin (or toxins) by which the manifestations are caused. And it is not true, as is supposed by some, that botulism is caused by the proteid bacterial poisons alone (commonly known as toxins), but by certain of the basic crystalline products of decomposition, known as ptomains, as, for example, mytilotoxin, a ptomain isolated by Salkowski and Brieger from contaminated mussels.

Not uncommonly, ptomains are regarded as necessarily poisonous substances. This, however, is far from being the truth. They are products of decomposition brought about by micro-organisms which break up the complex organic matters into less complex compounds, which in turn are split up into products of diminishing complexity, until the final products are water, hydrogen, carbonic acid, sulphuretted hydrogen, ammonia, nitrogen, and salts. During this process of decomposition, at different stages, the ptomains, which are organic bases, are formed. Some are poisonous, but the great majority of those thus far isolated are wholly inert. All contain nitrogen, but not all contain oxygen, thus resembling the vegetable alkaloids. The variety of ptomains formed depends upon the kinds of micro-organisms at work, the nature of the substance undergoing decomposition, and the conditions of temperature, access of air, and other attendant circumstances. One species of bacteria may produce no ptomains from one kind of material, and poisonous or inert ones from another. At one stage of decomposition no ptomains may be formed, at another several may be present, and later these may have disappeared completely, for they are but intermediate products.

Brieger has isolated a number of varieties of ptomains from decomposing meats and fish, including neurine, choline, and one which appears to be identical with muscarine (all three of these are antagonized in their poisonous action by atropine), and neuridine, putrescine, cadaverine, another which produces effects similar to those of curare, and others. Vaughan discovered the very important ptomain, tyrotoxicon, in milk and cheese.

Many of the poisonous compounds formed during putrefaction retain their active character long after the organisms through whose agency they have been produced have perished. This was noted as early as 1856 by Panum, who found that the poison of certain putrid meat retained its activity even after it had been boiled 11 hours, and his

observation has repeatedly been confirmed by others. Naturally, no amount of cooking will suffice to render such meat harmless.

The physiological action of these poisons is widely different. Some cause intense gastro-intestinal irritation, some act directly on the heart, some on the central nervous system, and some on particular centers. Very different effects are produced in different people, owing perhaps to varying degrees of susceptibility and also to unequal distribution of the poison through the mass of meat.

The extent to which the putrefactive process has advanced is by no means of such importance in the determination of the question of possible ill effects, as the nature of the engaged bacteria and of their products, for meat may be extremely putrid and yet not be poisonous, and, on the other hand, may be apparently normal and yet deadly in its effects. Many savage peoples prefer putrid fish and meat, and the more rotten it is, the greater their enjoyment in its consumption. In less degree, the same is true of many of the most enlightened people, who prefer game when decomposition is fairly well advanced. On the other hand, the severest outbreaks of food-poisoning have followed the eating of meat apparently not undergoing decomposition. Indeed, the majority of persons will reject meat which has the slightest taste or odor indicating beginning putrefaction, since even this makes it repugnant to the senses. In many cases, the poisonous principles appear to be developed after the meat has been eaten, through changes occurring within the intestines.

The bacteria which have thus far been shown to have been the cause of outbreaks of meat- and fish-poisoning include certain spore-bearing anaërobes isolated by Van Ermengem (*B. botulinus*), and Klein (*B. enteritidis sporogenes*), a number of derivatives of *B. coli* isolated by Gaertner (*B. enteritidis*), Basenau (*B. bovis morbificans*), Kaensche (*B. Morseelensis* and *B. Breslaviensis*), Gaffky and Paak (*B. Friedebergensis*), Abel, Günther, and others, besides *B. proteus vulgaris*, *B. proteus mirabilis*, *Staphylococcus pyogenes flavus*, and others. The first mentioned (*B. botulinus*) produces an extraordinarily virulent toxin, which has been the subject of careful investigation, which has proved that it is related closely to the toxins of diphtheria and tetanus.

Study of a bacillus which Trautmann[1] isolated as the cause of an outbreak of poisoning at Düsseldorf, and comparison thereof with cultures of *B. Friedebergensis*, *B. enteritidis*, *B. Morseelensis*, *B. bovis morbificans*, *B. Breslaviensis*, and of the organisms isolated by Fischer, Abel, and Günther, and also of the various strains of paratyphoid bacilli, led him to the conclusion that, while these several kinds present slight differences in morphology and cultural peculiarities, they show no fundamental difference and are merely varieties of one and the same organism. Others have called attention to the similarity of symptoms in meat-poisoning (not botulism) and paratyphoid, and the belief is growing that the differences in the nature and severity of symptoms and in the order of their appearance are dependent upon the slight racial differences in the bacteria and upon the degree of virulence and

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XLV., p. 139, and XLVI., p. 68.

individual susceptibility. Many outbreaks of meat-poisoning have been indistinguishable from paratyphoid, and many of severe form have been mistaken for true typhoid. Trautmann believes that the typical meat-poisoning is the hyperacute, and paratyphoid the subacute, manifestation of an etiologically similar disturbance, and he places all of the exciting causes under the general head of *B. paratyphosus*.

Onset and Course of Symptoms.—The first symptoms in cases of poisoning by fish and meats may occur within an hour or two after eating or may be delayed a number of days. In one outbreak cited (see Poisoning by Herrings, page 61), in which 5 persons were seized, the initial symptoms appeared in 2, 3, 5, 7, and 9 days respectively; ordinarily they appear within a few hours—3, 6, 12. When numbers of persons are affected by the same food, the onset is by no means uniform. In the Ellezelles case (see page 69), in which 20 persons were seized, the time in which the symptoms first were manifested ranged from 3 to 36 hours, but as a rule, it is the appearance within the same day of similar symptoms in a number of persons which calls attention to the food supply as a common cause of the trouble. Poisoning by ptomains is manifested generally within a few hours.

In cases of rapid onset, the progress either to recovery or a fatal termination is commonly short, but may be sometimes a matter of months, and in these exceptional cases eventual recovery is probable. The shortest case on record is that of mussel-poisoning at Wilhelmshaven (see page 60), in which 1 victim died in 2, another in 3, and 2 others in 5 hours after eating.

A peculiar tendency to relapses often is observed. The patient begins to improve, when suddenly the original symptoms reappear with equal, greater, or diminished intensity. Improvement may be succeeded again by a relapse, and the alternation may obtain for many months. The toxins secreted by the original invading bacteria are antagonized by antitoxins produced by the system and improvement occurs; then during this interval the spore-bearers find opportunity to develop a new crop of bacteria, which, again producing toxins, cause a recurrence of the original symptoms.

Nature of Symptoms.—As has been stated, the effects produced vary very greatly, but the symptoms of abdominal disturbance and of poisoning of the central nervous system are the most constant as well as most predominant. Fever may or may not be present; usually it is not, but in some outbreaks temperatures exceeding 104° F. have been recorded. In some cases, the temperature is subnormal. Disturbance of the circulation is more common than fever, the pulse being small and rapid, and sometimes dicrotic. In a few instances, marked embarrassment of respiration has been noted. In most of the recorded cases, no mention is made of involvement of the kidneys, but in some instances evidence of acute nephritis has been observed. Dysuria, anuria, and paralysis of the bladder are not uncommon. In most cases, extreme muscular weakness is a prominent symptom, and not infrequently muscular pains and cramps. While diarrhœa, long continued, is a most common occurrence, in many cases most obstinate constipation,

sometimes following diarrhœa and sometimes present from the first, is noted. In some cases abdominal symptoms are by no means prominent, and in others they are practically the only ones observed. The symptoms of involvement of the nervous system include those mentioned above, and drowsiness or insomnia, headache, dizziness, delirium, diminished co-ordination of movement, numbness, cramps, convulsions, and paralyses.

Post-mortem Appearances.—The post-mortem appearances observed in cases of poisoning are very inconstant, both as to extent and kind, and are by no means proportionate to the severity of the symptoms. Even when a number of individuals succumb to the same influences, the appearances may show but little in common. Thus, in the Welbeck case (page 66), one showed nothing more than a few bright red patches in the stomach; a second, congestion of the gastro-intestinal mucous membrane; and a third, severe parenchymatous inflammation with distention and plugging of the arterioles and capillaries of the Malpighian corpuscles by emboli of bacteria. The most extensive changes observed are those occurring in poisoning by mussels and oysters, in which cases the extremely rapid onset and the very short course to a fatal termination suggest the action of poisonous ptomains. Indeed, animal experimentation has demonstrated that certain of these compounds produce these very changes, which include great enlargement of the spleen, punctiform ecchymoses and hemorrhagic infarctions, and fatty degeneration of the heart, liver, and kidneys. In cases of meat-poisoning, the appearances noted range from a few red patches in the intestines to severe gastro-enteritis with destructive changes in all the principal viscera.

Character of Meats which Cause Poisoning.—In general, outbreaks of poisoning are caused by the meat of animals slaughtered while suffering from diseases other than those which are best known to the public because of the great destruction wrought when raging in epidemic form; but they may also be traced to the flesh of perfectly healthy animals which has become contaminated, both in the raw and cooked states, by poison-producing bacteria.

The most dangerous forms of meat-poisoning are those due to the pyæmias, septicæmias, and pneumo-enteritis, and the greatest intensity of action is produced by preparations made from the entrails.

In a majority of the reported outbreaks, the meat has been consumed either raw or only imperfectly cooked, or after being kept a day or two after being cooked. The meats most commonly the cause are pork and its preparations, and veal. Both yield a considerable amount of gelatin, and this fact has been suggested as having an important bearing, since this material is a medium which offers favorable opportunities for the growth of bacteria.

Most of the reported outbreaks have occurred in the countries of Europe, where the meat supply, in consequence of being very restricted, is utilized to its fullest extent. Viscera which with us are rejected as refuse, and the flesh and viscera of animals slaughtered in consequence

of sickness, with the consent and approval of official veterinarians, are sold and eaten. Another reason for the frequency of the outbreaks is a very common preference for scraped or minced raw meats and for sausages of domestic manufacture made under most unsanitary conditions.

Veal.—According to Vallin, in a communication to the Academy of Medicine in 1895, a large number of outbreaks of poisoning in Germany, Switzerland, and elsewhere are due to the consumption of veal from animals either sick or too immature. Darde and Drouineau[1] relate that they have seen nearly the whole strength of a military company, 135 out of 147, poisoned by eating roast veal. The symptoms appear generally in from 6 to 24 hours, and include vomiting, purging, and great prostration. Dilatation of the pupil is common, but not constant. Occasionally, skin eruptions appear.

By Vallin,[2] and by others as well, it is deemed probable that veal-poisoning is due largely to the existence of septic pyæmia and septic pneumo-enteritis in calves, and Van Ermengem has suggested that a number of septic diseases of these animals are grouped commonly under the head of diarrhœa. He fed the fresh meat of one of these calves to mice and guinea-pigs, which died within a few days with enteritis. From the bone marrow he isolated an organism which appears to be related closely to Gaertner's *B. enteritidis*, and which on inoculation into animals produces a fatal enteritis.

Beef.—Beef-poisoning has been noticed with considerable frequency, following the use of meat from animals slaughtered while sick, and it has been pointed out by several observers that certain septic diseases of cattle are especially prone to render meat poisonous. These include the septic form of calf paralysis, hemorrhagic enteritis of calves, septic metritis of cows, various intestinal disorders, the septico-pyæmic diseases, and a number of others. Gaertner's *B. enteritidis* was discovered by him originally in the flesh of a cow that had been slaughtered on account of a severe diarrhœa, and in the spleen of a person who died in consequence of eating it. He showed that not only the bacillus, but also its boiled bouillon cultures, are highly toxic.

Many deaths have been recorded as a consequence of eating the cooked meat of cows slaughtered on account of puerperal fever, and it was from such an animal that Basenau isolated *B. bovis morbificans*. This cow showed such lesions of the viscera that the director of the Amsterdam abattoir forbade the use of the meat.

Basenau[3] has examined the flesh of beeves which had succumbed to a variety of diseases, and he has isolated a number of species of bacteria bearing a close resemblance to *B. bovis morbificans*, all of which are fatal to mice. Some of them produce poisonous matters which withstand boiling without impairment of their properties. Ordinary inspection being useless for determining whether such meat is infected,

[1] Archives de Médecine et de Pharmacie militaires, 1895.
[2] Revue d'Hygiène, 1895, XVII., p. 473.
[3] Archiv für Hygiene, XXXII., p. 219.

he recommends that bacteriological and feeding experiments should be instituted together within 24 hours after slaughtering. If no colonies are observed at the end of 24 hours and no bacteria are seen in the tissues, the meat may be regarded as safe to eat. If colonies are yielded, the acceptance or rejection of the meat must depend upon the results of the feeding experiments. If the mice fed on the raw meat die and those fed on the cooked meat survive, it may be concluded that the meat is safe, if thoroughly cooked. If both die, the meat should unhesitatingly be condemned.

Sausage.—Sausage has long been recognized as a very common cause of poisoning, and has a much larger record of accidents than any other meat or meat compound. This is due in large part to a very common practice of making use of all manner of uninviting fragments and scraps of meat, offal, and the flesh of sick and ill-conditioned animals in preparing sausage meat, and perhaps to a greater extent to the extremely unsanitary methods of manufacture which obtain in those districts where this form of poisoning is most prevalent. In many instances, the symptoms caused are due to the presence of ptomains, and in many to the contained bacteria and their toxins.

In most instances, it is impossible to fix the blame upon any individual constituent, nor aside from its scientific interest is this of special importance. The symptoms present as wide variations in character as are observed in any other form of food-poisoning

The process of smoking, to which certain varieties of sausages are subjected, while not destructive to the bacteria of putrefaction, is often successful in masking any unpleasant smell or taste due to change.

Cases Illustrative of Poisoning by Fish and Meat.

Poisoning by Mussels. Case I.—At Wilhelmshaven, in 1885, several longshoremen and their families, 19 persons in all, were stricken with very severe symptoms shortly after eating a meal of mussels. The symptoms were in general the same in all, regardless of the amount eaten, and included nausea and vomiting without abdominal pain or purging, trembling, constriction of the throat, dizziness, and diminished coördination of movement similar to that due to alcoholic intoxication. There was no fever. Speech was difficult and thick, and in a short time the legs were unable to support the body. The pupils were dilated and unresponsive to reaction tests. The extremities were cold and numb. Four deaths occurred, one within two hours, one in three and a-half, and the others within five hours from the time of ingestion. The autopsy in the only case examined revealed enteritis, enormous enlargement of the spleen, numerous hæmorrhagic infarctions, and fatty degeneration of the heart, liver, and kidneys.

In this case, the sudden onset and rapidly fatal termination indicate a true poisoning rather than an invasion of the system by bacteria, and, indeed, the poison was proved by Salkowski and Brieger to be a ptomain, to which they gave the name mytilotoxin.

CASE II.—Dr. James S. Combe,[1] of Edinburgh, reported, in 1828, an outbreak which involved a large number of persons of the lower class ranging in age from 2 to 70 years. The first case seen was a man of 60, who complained of thirst, heat in the mouth, difficulty in swallowing, tension about the jaws and throat. The pulse was small and weak, the respiration normal, the surface cool. The hands were numb and the legs unable to support the body. Recovery followed purgative treatment. He had supped the evening before with a friend, who died during the night. They had eaten mussels boiled with salt, but had noticed no peculiarity of taste. The next case seen was that of a man of 30 who, on the previous evening, had picked a few mussels, not over five or six, and had eaten them raw. No effects were noticed until morning, excepting slight burning of the lips and tongue. On attempting to get up he found that he could not stand, although he, like the first, could move his legs about in bed.

Although hundreds of cases, with many deaths, were said to have occurred, in consequence of which the magistrates issued a warning against the use of mussels, Dr. Combe found but thirty cases with two deaths. In all, the symptoms presented a striking uniformity, though they varied much in severity. Most of the victims had eaten the mussels boiled with salt and pepper, and none had noticed any unusual taste. In general the symptoms appeared in an hour or two.

The man who died had vomited a few hours after eating. He lay down, had occasional general trembling, was rational to the last, and died as if by increasing weakness. On section a few dark-red patches were found in the ileum. The stomach was empty and presented no abnormal appearance. The other fatal case was that of a woman who died in three hours after eating. The autopsy revealed a full stomach containing mussels and potatoes, and beyond a few red patches in the intestine the viscera were quite normal.

In his report, Dr. Combe referred to a case related by Captain Vancouver,[2] a number of whose men ate a breakfast of roasted mussels. Soon, several were seized with numbness about the face and extremities, followed by involvement of the whole body. One man, who died in five and a half hours after eating, was unable to swallow, and though he could row in the boat while sick, he was unable to stand on leaving it.

Poisoning by Herrings.—A case involving five persons, reported by R. David,[3] is remarkable for the variety of manifestations, the length of time that elapsed before the appearance of the symptoms, and, in two of them, the severity and duration of the illness. The afflicted persons, adult members of one family, ate on March 19, 1898, some raw red herrings, which gave off odor indicative of commencing putrefaction. Each ate the same amount, a whole fish, but whether each fish was equally advanced in decomposition cannot, of course, be determined, and the differing degrees of severity of effects may be explained

[1] Edinburgh Medical and Surgical Journal, 1828, XXIX. p. 86.
[2] Voyage of Discovery, Vol. IV., p. 45.
[3] Deutsche medicinische Wochenschrift, 1899, No. 8.

by unequal susceptibility. The father and mother aged, respectively, 65 and 67 years, suffered least; the son, aged 31, was affected more seriously; the two daughters presented unusually severe and complicated symptoms.

The first effects were manifested by the son, who, on the second day, was seized with loss of appetite, disagreeable eructations, vomiting, diarrhœa, dryness of the throat, and general weakness. On the following day, he was better, but soon became worse. Diarrhœa was followed by obstinate constipation, which finally yielded to cathartics. Five days later, he had dimness of sight, which was followed after a week by double vision and difficult deglutition. The symptoms gradually abated, and on May 27th there was distinct improvement of sight. On June 2d glasses were hardly needed.

The mother first showed symptoms on the fifth day, when nausea, constipation, and dryness of the throat appeared. Several days later she had double vision and difficult deglutition.

The father's case began on the ninth day and presented similar symptoms, which disappeared in six weeks.

One of the daughters was seized on the third day with bad taste in the mouth, constipation, and dryness of the throat, followed in six days by dimness of near vision, then by double vision, paralysis of accommodation, and difficult swallowing. As was the case with the others, the temperature, circulation, and urine remained normal. On May 2d, there was complete inability to swallow and it was necessary to introduce food by means of a stomach-tube. There was slight ptosis of the right eye, then of both; the voice was nasal; the gait was affected and the pulse became very small, though not very rapid. On May 9th, bladder symptoms, which had been gradually appearing, culminated in paralysis of that organ, and after the 13th, a variety of bladder and abdominal symptoms appeared. In the first part of July, she felt completely well, but a month later she suffered a slight relapse, with reappearance of constipation, difficult deglutition, and disturbance of vision, which persisted with varying intensity into September. Complete recovery did not occur until October, almost seven months after the initial symptoms.

The other daughter first showed symptoms after the lapse of a week. These were in the main like those of her sister, but were more severe and extensive. She began to improve in May, and then ensued alternate improvement and loss of ground, better one day and worse the next. On the 15th, there was pain in the left hypochondrium; on the 17th, an eruption like that of scarlet fever over the whole body, with albuminuria, but no casts. On the 19th, severe pain in the left hypochondrium, less in the right, and tenderness in the region of the kidneys, with epistaxis, disappearance of the rash, slight desquamation, and improved vision. At the end of May, the albuminuria and pain in the region of the kidneys had nearly disappeared, and deglutition was perfect. On June 2d, heart complications appeared, which persisted into November, when hypertrophy was established. In

August, after a general improvement, there was a relapse like that which occurred in the case of her sister. Improvement was well established in October, and in November she had almost wholly recovered.

Unfortunately, it was impossible to make a bacteriological and chemical examination of the fish, because no material was obtainable.

Poisoning by Salmon.—Professor Vaughan[1] reports the following case: "K., a very vigorous man of 34 years, ate freely of canned salmon. Others at the table with him remarked that the taste of the salmon was peculiar, and refrained from eating it. Twelve hours later, K. began to suffer from nausea, vomiting, and a griping pain in the abdomen. Eighteen hours after he had eaten the fish, the writer saw him. He was vomiting small quantities of mucus, colored with bile, at frequent intervals. The bowels had not moved and the griping pain continued. He was covered with a scarlatinous rash from head to foot. His pulse was 140, temperature 102° F., and respiration shallow and irregular." After appropriate treatment he began to improve. "The next day the rash disappeared, but the temperature remained above the normal for four or five days, and it was not until a week later that the man was able to leave his house." Vaughan examined the salmon and found a micrococcus present in great numbers. This organism, grown for twenty days in a sterilized egg, produced a most potent poison. The white became thin, watery, and markedly alkaline, and ten drops sufficed to kill white rats.

Poisoning by Oysters.—Case I.—The following case, which ended fatally, is reported by Brosch.[2] An officer ate a number of oysters toward midnight, and within 6 hours was seized with headache, pain in the side, nausea, dimness of sight, difficult deglutition, retention of urine, and salivation. Toward noon, right facial paralysis, dilatation of the right pupil, and thickness of speech appeared, followed shortly by cyanosis, ptosis of the right eyelid, great muscular relaxation, and paralysis of respiration. Autopsy revealed punctiform ecchymoses in various parts, enlargement of the spleen, and fatty degeneration of the liver and kidneys.

Case II.—Another fatal case is recorded by Casey:[3] "H. P., about 32 years of age, ate 8 oysters for supper, remarking at the time that one of them was bad. Others of the same lot appeared to be quite fresh and were eaten by other persons with impunity. Symptoms of poisoning began about 12–14 hours later, with pain in the back, soon followed by violent pains in the stomach, frequent vomiting, and intense thirst. The bowels did not act. These symptoms continued until the following morning, when the pulse, which had been small and quick, became almost imperceptible, the fingers shrunken, the nails blue. The tongue was at that time dark and swollen, and swallowing difficult. There were occasional spasms of the arms. A little later, the jaw

[1] Ptomains, Leucomains, Toxins, and Antitoxins, 1896, p. 56.
[2] Wiener klinische Wochenschrift, 1896, No. 13.
[3] British Medical Journal, March 3, 1894, p. 463.

became set, and soon, after a sudden struggle for breath, he died, 41 hours after eating the oysters. At the post-mortem examination, the heart was found to be very soft and relaxed and contained fluid blood. The kidneys and spleen were also very soft and congested; the stomach empty and darkly congested; the peritoneum was thickly studded with flecks of lymph."

Poisoning by Veal.—Boyer[1] reports the following case of sextuple poisoning by veal. The persons affected were members of one household, and ranged widely in point of age, the youngest being children of 3 and 6 years. The symptoms appeared in the night, about 6 hours after the food was taken, and began with vomiting and violent colic. In the morning, all had intense gastric irritability, coated tongue, pain on pressure, especially in the right iliac fossa, rumbling, slight tympanites, and scanty urine. The cook had markedly dilated pupils, a sensation of suffocation, constriction and dryness of the throat, and intense suffusion of the face. The child of 6 had dilated pupils and disturbance of vision, and finally pain and stiffness of the muscles of the neck. The younger of the two children and the mother were affected less than the others, and made a more rapid recovery. The chambermaid had at first a certain degree of aggravation of symptoms, with a tendency to syncope and great muscular weakness, which latter effects were marked also in the case of the cook, who continued for some time to be troubled by dilatation of the pupils and disturbed vision. At the end of nine days, there was no evidence of danger, and the two most severely affected were well on the way to recovery.

Unfortunately, no bacteriological examination was made either of the meat or the discharges, but the nature of the symptoms leaves no room for doubt as to their cause.

Case II.—Drs. Wilkinson,[2] Ashton, and Durham have recorded an extensive outbreak of poisoning due to imperfectly cooked veal pies. All the cases, over fifty in number, presented very similar symptoms, the chief of which were severe and uncontrollable vomiting and diarrhœa, accompanied at first by shivering, and followed by collapse. In some there were violent abdominal pains, and in several the abdomen was swollen and tender. Many had severe pains in the back. The symptoms began in from 5 to 14 hours after eating, and, as a rule, were severe from the start. The motions were first grass-green, then dark green, and highly offensive. The severity of the diarrhœa increased on the second day; one patient was purged 40 or more times in a single day. In very few cases, the dejecta contained a little blood.

In the worst cases, the patients became semi-comatose, restless, and delirious in the course of a few hours. Occasionally, there were disturbances of vision, which lasted until the temperature, which ranged from 100° in the mildest to 104.5° F. in the severest cases, became normal. The pulse was very rapid, weak, and dicrotic. Many of the pa-

[1] Lyon médical, May 14, 1899.
[2] Public Health, January, 1899, and British Medical Journal, December 17, 1898.

tients were markedly cyanotic and had more or less difficulty in breathing. Some had cramps, and nearly all had muscular pain and stiffness. In very many cases, herpes appeared about the lips on the third to the sixth day, and some had a rash followed by desquamation. Convalescence in the severe cases was prolonged; some were still weak after three and a half months. Four cases terminated fatally, and in two of these, autopsies were secured. The brain surface showed slight congestion; the small intestines showed congested patches, which became larger and more numerous lower down, and did not correspond with Peyer's patches. The whole lower third was highly congested, and contained yellow diarrhœic fluid. Otherwise the organs of the body were in a fairly healthy condition.

Investigation of the cause of the outbreak yielded the following facts: On July 26th, an apparently healthy calf was slaughtered, and two days later the fore quarter and breast were delivered to a baker, who made the meat into the pies which were shown to have been the cause of the outbreak. Other portions of the animal were sold to others, who made pies which caused no trouble. A portion of a knuckle end, which was in the possession of the butcher when the investigation was begun, was to all appearances perfectly good.

The baker to whom the trouble was traced made, on the day he received the meat, 160 veal pies and 108 pork pies. The pastry was the same for the entire lot, and both kinds were treated to the same lot of jelly, which was made by boiling the veal bones with two pigs'-feet in 4 quarts of water. Inasmuch as the pork pies caused no disturbance of any kind, no responsibility could be attached to the pastry or to the jelly. The veal pies were baked in not less than 3 nor more than 5 batches, hence the batches would have included about 32, 42, or 53 pies. The time occupied in baking each batch was said to have been about 20 minutes. The number of persons affected was over 50 and as in some cases single pies were shared by 2, 3, and 4 persons, it is obvious that less than 50 pies caused all the trouble. Since no other parts of the animal caused any sickness, there can be no doubt that the contamination of the meat occurred after the sale and delivery.

According to the findings of Dr. Durham, based on a study of the blood of a number of the patients as to the behavior of the serum when tested for clumping properties with various micro-organisms, with controls of serum from normal persons, the outbreak was due to *B. enteritidis*. This limitation of the inquiry was necessitated by the fact that it was impossible to secure either one of the pies, or part of one, or any of the first vomitings. The conclusion arrived at, strengthened by the fact that all 4 fatal cases were from pies which were 2 or more days old when eaten, which period allowed enormous multiplication, makes most probable the further conclusion that one whole batch was cooked so insufficiently as to preclude the killing of the organisms, which, according to Basenau, cannot survive exposure for 1 minute to a temperature of 70° C.

Poisoning by Pork.—CASE I.—Meredith Young[1] records a case of pork-poisoning in which 5 persons were affected. The offending meat was three-quarters of a pound of "pig's cheek," which was eaten at half-past four in the afternoon, between which time and the onset of symptoms nothing else was eaten. On the following morning, Mr. A. was seized suddenly with vomiting, purging, and severe abdominal pain, and shortly afterward became very feverish and weak, and suffered from severe frontal headache. His wife had severe abdominal pain, and toward noon was strongly purged. She suffered nausea, retched, but could not vomit, had fever and severe headache, and was much more prostrated and took more time to recover than her husband. She was unable to ingest food for 3 days. The daughter was taken sick at the same time and with the same symptoms, though less severely. Her chief symptom was an overpowering tendency to sleep. A fourth person, who ate but little as compared with the amounts ingested by the others, was purged slightly, but suffering nothing more. The remaining member showed no effects until during the second night. On the following morning, she was feverish, had severe headache and abdominal pain, and retched unsuccessfully. Purging did not occur until the afternoon. As was the case with the daughter, the most prominent symptom after the onset was somnolence. Recovery followed in every case. Investigation showed that the cheeks had been cooked 2 days before, and had been placed together to cool and "set." It was estimated that between 50 and 60 persons had purchased of them, but all but a small proportion were unknown to the seller, and so no systematic inquiry could be made. Only 4 could be followed up, and 2 of these reported no trouble; a third was made severely sick and lost 2 days' work, and the fourth, after eating, drank so much beer that he was made sick and lost it all by vomiting, and yet was affected like the others, but not so actively. It was impossible to procure any of the meat or vomited matter or dejections for bacteriological examination.

CASE II.—At the Seventh International Medical Congress, held in London, in 1881, Ballard[2] read before the section on State Medicine an account of a very serious outbreak, now generally known as the "Welbeck case." This involved 72 persons, who attended a sale of timber and machinery on the estate of the Duke of Portland at Welbeck, which lasted from Tuesday, June 15, 1880, through the week. Refreshments were served by the keeper of a public house, and among the articles furnished were seven hams, to which the entire trouble was traced. While many complaints were made that the ham was not sufficiently cooked, that the fat was yellowish or greenish, that it was too salt, that it "tasted queer," and that it had no true flavor of ham, many made no complaint, and no one said that it was tainted. Of the 72 persons seized, 4 died. The history of 3 of these follows:

1. W. W., aged 64, ate ham on Wednesday and Friday, and

[1] Public Health, June, 1899.
[2] Supplement to 10th Annual Report of the Local Government Board, 1881, p. 36.

was seized on Friday night, when he complained of feeling cold. On Saturday morning, he ate but little and said he ached all over. In the course of the day, he suffered from vomiting and diarrhœa, with severe pain and cramps in the legs. The evacuations were exceedingly offensive and were passed involuntarily. The pulse was 128; temperature not taken. On Monday, he began to collapse, and on Friday, he died. The post-mortem examination revealed little that was noteworthy, but microscopic examination of the kidneys showed parenchymatous inflammation, and distention and plugging of the afferent arterioles and capillaries of the Malpighian corpuscles by emboli of bacilli.

2. Mrs. L., aged 62, ate some scraps of the ham on Wednesday, and was seized on Friday with faintness, diarrhœa, vomiting, and abdominal pain. On the following day she fell into a state of collapse, and on the following Tuesday she died. The mucous membrane of the stomach and intestines was highly congested; otherwise the autopsy revealed nothing abnormal.

3. Mr. S., aged 37, ate four sandwiches on Thursday. In the evening he vomited, and diarrhœa began. In the morning of the following day, he complained of burning pain in the lower part of the abdomen. The vomiting and purging continued. Though cold and clammy to the touch, he complained that he was "all on fire." He had cramps in the legs and was very restless. His mind was clear to the last. The discharges were, at first, watery and offensive, and later were dark green in color. He was very thirsty and drank freely of water. He died on the following Friday. Only a partial autopsy was made. This revealed bright-red patches on the mucosa of the stomach.

The period of incubation was accurately determined in 51 cases; in 5 it was 12 hours or less, in 34 it was between 36 and 48, and in 4 it exceeded 48 hours. In many cases the onset was sudden, and in others it was preceded by greater or less indisposition. The most constant symptom was diarrhœa. "In about a third of the cases the first definite symptom was a sense of chilliness, usually with rigors or trembling, in one case accompanied by dyspnœa; in a few cases it was giddiness with faintness, sometimes accompanied by a cold sweat and tottering; in others the first symptom was headache or pain somewhere in the trunk of the body, *e. g.*, in the chest, back, between the shoulders, or in the abdomen, to which part the pain, wherever it might have commenced, subsequently extended.

"In one case the first symptom noticed was a difficulty in swallowing. In two cases it was intense thirst. But, however the attack may have commenced, it was usually not long before pain in the abdomen, diarrhœa, and vomiting came on, diarrhœa being of more certain occurrence than vomiting. The pain in several cases commenced in the chest or between the shoulders, and extended first to the upper and then to the lower part of the abdomen. It was usually very severe indeed, quickly producing prostration or faintness with cold sweats. It was variously described as 'crampy,' 'burning,' 'tearing,' etc.

"The diarrhœal discharges were in some cases quite unrestrainable,

and (where a description of them could be obtained) were said to have been exceedingly offensive, and usually of a dark color. Muscular weakness was an early and very remarkable symptom in nearly all cases, and in many it was so great that the patient could only stand by holding on to something. Headache, sometimes severe, was a common and early symptom; in most cases there was thirst, often intense and most distressing. The tongue, when observed, was described usually as thickly coated with a brown velvety fur, but red at the tip and edges.

"In the early stage, the skin was often cold to the touch, but afterward some fever set in, the temperature arising in some cases to 101°, 103°, and 104° F. In a few severe cases where the skin was actually cold, the patient complained of heat, insisted on throwing off the bedclothes, and was very restless. The pulse in the height of the illness became quick, counting in some cases 100 to 128.

"The above were the symptoms most frequently noted. Other symptoms occurred, however, some in a few cases, and some in only solitary cases. These I now proceed to enumerate. Excessive sweating, cramps in the legs, or in both legs and arms; convulsive flexion of the hands; aching pain in the shoulders, joints, or extremities; a sense of stiffness of the joints; prickling or tingling or numbness of the hands, lasting far into convalescence in some cases; a sense of general compression of the skin, drowsiness, hallucinations, imperfection of vision, and intolerance of light.

"In three cases (one that of a medical man) there was observed yellowness of the skin, either general or confined to the face and eyes. In one case, at a late stage of the illness, there was some pulmonary congestion, and an attack of what was regarded as gout. In the fatal cases death was preceded by collapse like that of cholera, coldness of the surface, pinched features and blueness of the fingers and toes, and around the sunken eyes. The debility of convalescence was in nearly all cases protracted to several weeks.

"The mildest cases were characterized usually by little remarkable beyond the following symptoms, viz., abdominal pains, vomiting, diarrhœa, thirst, headache, and muscular weakness, any one or two of which might be absent."

Investigation of the hams showed absence of trichinæ and the presence of a bacillus, which on inoculation into animals was found in most cases to produce a pneumonia.

The period of incubation indicates that in these cases there was a true bacterial infection.

Case III.—Another epidemic investigated by Ballard[1] involved a far greater number of persons and had an unusual attendant mortality, nearly 500 persons out of a population of about 100,000 (Middlesbrough) dying during the year of a peculiar form of pleuro-pneumonia.

The cause of this remarkable epidemic was proved to be the consumption of what was known as "American bacon," a food product

[1] Supplement to 18th Annual Report of the Local Government Board, 1889, p. 163.

prepared from imported salt pork at a number of local establishments conducted under most unsanitary conditions. Twenty samples of bacon, some obtained at shops and some at the homes of victims, were examined, and fourteen were found to be distinctly poisonous to animals. The lesions discovered in the dead animals were of the same nature and extent of those in the organs of the persons who had died. These included destructive changes in all the principal viscera, and more particularly in the lungs. Dr. Klein discovered in the lung a short bacillus which had never before been described. Inoculation experiments on animals produced results identical with those following feeding experiments with the so-called bacon.

Case IV.—A remarkable outbreak due to raw pickled ham has been recorded by Van Ermengem[1] and carefully investigated by himself and others. More than twenty members of a musical society at Ellezelles, in Belgium, were seized with serious illness after eating the greater part of a raw pickled ham; three died within a week, and ten lay in a critical condition. Other parts of the animal from the same pickling tub were eaten in a raw state without ill effects, and pieces of the particular ham had been consumed a short time before, also without ill effects. Only those persons who ate of the ham were seized with the very peculiar train of symptoms recorded. Most of them were seized in from 20 to 24 hours, 3 in less than that time, and a few as late as 36 hours after eating.

The first symptoms were gastric pain, nausea, and vomiting of undigested food and gelatinous blackish matters. Instead of diarrhœa, which one would expect, there was obstinate constipation in all but 2 cases, and the first dejections, with or without cathartics, were black and viscid. In every case, in from 36 to 48 hours, there were profound disturbances of vision—amphodiplopia, marked dilatation of the pupils, with absence of reaction to light, ptosis of both lids, and a peculiar fixed stare. There was burning thirst with a strangling sensation in the throat. Swallowing, even of liquids, was difficult or impossible, and every attempt was accompanied by choking.

In some instances, the saliva was suppressed and the mucous membrane dry and glossy. The voice was weak, and with some there was total aphonia. Dysuria and anuria were common. There was but little disturbance of respiration and circulation; the pulse never reached over 90, respiration was quiet, temperature normal. Consciousness and general sensibility remained unimpaired throughout, except in the fatal cases, in which alone, several hours before death, there occurred collapse, dyspnœa, small irregular pulse, light delirium, and coma.

There was obstinate insomnia in many, during the first period. The extremities and trunk muscles showed neither complete paralysis nor atrophy, but there was great general muscular weakness, and slight movements caused extreme fatigue. After two or three weeks, the eye symptoms began to improve. The dilated pupils contracted, the cloudiness disappeared, and the half-paralyzed eyelids regained their power.

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXVI., p. 1.

Diplopia disappeared only when both eyes were fixed laterally. Paralysis of accommodation lasted a long time after the disappearance of all the other symptoms, and normal vision did not return until after six to eight months.

Autopsy in two cases showed no characteristic changes in the organs, only extensive hyperæmia of the kidneys, liver, and meninges, and softening and unusual friability of the stomach walls. In one, the liver showed marked degeneration, and the brain punctiform hemorrhages. Neither the liver nor kidneys showed anything unusual on bacteriological examination, but the spleen yielded an anaërobic bacillus, which proved later to be capable of causing botulism.

The pig from which the ham came was killed some months previously, and what was not eaten at once was pickled in the usual way. During the time that elapsed between the pickling and the supper, the greater part of the animal had been consumed without causing any sickness, but the ham which was nearly intact was the last to be eaten, lay on the bottom of the tub, and was the only part that was immersed completely in the weak brine. What was left of it gave no odor of putridity, but had a distinct odor like that of rancid butter. That the ham had a bad taste, was agreed by nearly all who ate of it. It appeared normal to the eye, but was pale, like any meat that has been soaked some time in water. There was no evidence of decomposition, and no ptomains were detected.

Bacteriological examination proved in different parts the presence of a hitherto unknown spore-bearing bacillus in great abundance, the same organism as that isolated from the spleen of one of the victims. It produced an extraordinarily virulent toxin, which was isolated by Brieger from cultures supplied by the discoverer, by whom the organism was named *Bacillus botulinus*. The toxin is rendered inert by a temperature of 60° to 70° C., therein agreeing with other bacterial toxins thus far isolated.

Attempts to discover the organism in the feces of various animals and in filth of various kinds, and in specimens from where the pig was raised were negative in results.

Feeding-experiments, conducted on various kinds of animals with the meat itself and with aqueous triturations of it added to other foods, produced, as a rule, fatal results with the same train of symptoms as above mentioned. Subcutaneous injections of the watery extract produced the same results as feeding-experiments. The aqueous extract kept in the dark in a sealed tube retained its properties unimpaired for 10 months, and small pieces of the meat kept in cotton-stoppered tubes without special precautions retained their virulence even longer. The poison resists the effects of putrefaction, and proved to be equally poisonous after 4 days' standing in a mixture with feces, decomposing blood and urine, and filtration through porcelain. A fresh filtrate, to which were added *B. prodigiosus*, *B. proteus liquefaciens*, *B. fluorescens putrides*, and *B. coli*, was found at the end of a week to be as active as ever.

Poisoning by Beef.—Case I.—In December, 1841, more than 40

cases of poisoning occurred in New York City from eating smoked beef. As a rule the symptoms began several hours after eating, with pain and discomfort in the epigastrium, extending to the back and loins. Vomiting and purging were followed by great thirst and burning pain at the pit of the stomach, which became so irritable that it could tolerate neither food nor drugs. Extreme prostration followed, the functions of the nervous and muscular system being greatly affected. One victim died, and with the others convalescence was extremely slow. Autopsy revealed nothing beyond inflammation of the ileum.

Case II.—In May, 1888, at Frankenhausen, 58 persons were made sick by eating the meat of a cow killed while ill with diarrhœa and passed as edible by a veterinary. The symptoms were, in general, nausea, vomiting, diarrhœa, fever, drowsiness, dizziness, and great depression. Those who ate the meat in the raw state were seized without exception, and the severity of the seizure was directly proportionate to the amount eaten. One victim who ate a pound and a half died within 35 hours, while those who ate least suffered least. Those who ate the cooked meat fared differently. Not all were attacked, nor did the severity of the symptoms bear any relation to the amount taken. Thus, some who ate freely suffered but little, while very severe effects were caused by slight amounts of the meat, and even by small portions of the broth. Thirty-six who ate the cooked meat escaped altogether. From a portion of the meat, and from the spleen of the person who died, Gaertner[1] isolated *B. enteritidis*, which, since then, has been shown to have been the cause of numerous other outbreaks.

Case III.—In June, 1889, 137 persons, including 50 children, in and about Cotta, in Saxony,[2] were made ill by eating the meat of a cow slaughtered on June 17th, because of an inflammatory condition of the udder. On the 11th, she had suddenly stopped giving milk and had refused food and drink. The meat appeared to be normal in every way and was sold on the day after slaughter. The first cases appeared during the night of the day of sale. The majority of the victims had eaten the minced meat in the raw state, others only after it had been cooked, and some had eaten only broth. The butcher who sold the meat tasted as much as would cover a knife-blade, and suffered from diarrhœa, headache, and abdominal pain for three days. His assistant did the same, and fared even worse. In one case, the symptoms began with a chill; in another, with difficult deglutition, double vision, and anxiety; in the rest, with nausea, vomiting, diarrhœa, headache, abdominal pain, dizziness, great lassitude, restlessness, lethargy, and unquenchable thirst. In many cases, the eyes were glassy, and the pupils much dilated. The tongue was commonly dry and coated. The children affected were extraordinarily weak, and some had fever as high as 104.7° F. A bacillus isolated from the meat by Johne was found by Gaertner to differ in some respects from *B. enteritidis*.

[1] Correspondenz-Blätter des allgemeinen ärztlichen Vereins von Thüringen, 1888, No. 9.

[2] XXI. Jahresbericht ueber das Medicinalwesen im Konigreich Sachsen, p. 104.

Case IV.—Poisoning by canned corned beef at Sheffield, reported by W. N. Parker.[1] On October 11, 1899, a six-pound tin of corned beef was opened, and about two-thirds were sold, chiefly in quarter pounds. Beyond the fact that the meat seemed less solid than usual and the jelly rather oily, nothing unusual was noticed. It had no odor, its taste was normal, though quite salt, and but one customer found its flavor disagreeable. So far as is known, none who ate escaped; 24 persons ranging in age from 2 to 89 years were affected. The following serves as an example, though each case presented one or more symptoms peculiar to itself.

A woman of 35 ate 2 ounces of the meat at 12.30, and in 2 hours was seized with faintness, dizziness, and drowsiness, followed by nausea, and great muscular weakness, especially of the legs. Persistent vomiting with frequent retching soon occurred, accompanied by intense frontal headache, and followed by colic which was not relieved by purging. One hour after seizure, she was taken to the hospital, where she lay on a couch in a state of collapse with her knees drawn up. Her face was pale, with livid patches around the eyes, and bathed in perspiration. The skin was cold and clammy, the pulse small and rapid, the respiration shallow, the temperature subnormal, and the pupils dilated. Her stomach was washed out, and in a short time the pain and retching ceased, the character of the pulse improved, drowsiness was diminished, and only the headache and purging remained. Within an hour, the condition of collapse and other symptoms reappeared, but with less severity. The stomach was again washed out, and this time the good effects were permanent. On the following morning, all that was complained of was slight frontal headache.

The approximate latent period varied between one and three and a half hours, but in only 2 cases was it more than two and a half hours. Frontal headache was present in all but 4, vomiting in all but 1, pain in only 12, marked collapse in 12, profuse discharges in all but 6. The initial symptoms were the same in all; that is, drowsiness or giddiness, or both.

Only one case resulted fatally, that of a boy 7 years old, who ate 2 ounces. His symptoms were especially severe; collapse was very marked and he required constant stimulation. About 10 hours after the onset, he had a series of clonic contractions of the flexor muscles of the neck, arms, and legs. The movements were violent, rapid, and almost rhythmical, commencing first in the neck and arms, but soon affecting the legs. The eyes were fixed and staring, and the pupils widely dilated. After lasting an hour and a half, the convulsions ceased. They reappeared in half an hour, affecting first the right arm and right side of the face, but soon became general. The collapse gradually deepened, and the boy died 15 hours after seizure. Autopsy showed nothing more than a general hyperæmia of the stomach and intestines, with a few hemorrhagic erosions in the

[1] British Medical Journal, November 11, 1899.

gastric mucous membrane. A microscopic examination of the kidney showed cloudy swelling of the cortex, with a few scattered hemorrhages.

All the other victims convalesced rapidly and were discharged from the hospital within 48 hours. Stimulants, chiefly in the form of strychnine and brandy, were administered freely. The meat was examined bacteriologically about 11 hours after the tin was said to have been opened. In the outer parts of the meat, many species of organisms were found. The only organism present both in cultures from the centre of the meat and in those from the surface was the bacillus of Gaertner.

CASE V.—An outbreak at Mansfield, in which 65 persons became ill after eating the flesh of a cow slaughtered in consequence of traumatic pericarditis, has been reported by Wesenberg.[1] Only those who ate of the minced meat in a raw state or of the partly cooked liver were affected; those who ate of the well-cooked meat escaped without exception. The symptoms were vomiting and diarrhœa, violent headache and abdominal pain, general muscular weakness, dizziness and lassitude. The discharges were sometimes greenish, sometimes brownish, and always extremely offensive. With few exceptions, the symptoms abated in from 3 to 5 days, and all recovered except one, and that a doubtful case of a child who was not known with certainty to have partaken, and whose symptoms might have been due to other causes.

The unconsumed meat when received for examination was already fairly well advanced in decomposition and partly maggoty. All except one piece, which was faintly acid to litmus papers, was alkaline in reaction. Cultures on agar and in bouillon were made from a piece taken from a part which was apparently not yet in process of decomposition. Inoculation of the bouillon cultures and of small bits of the meat into white mice produced fatal results, in some cases within from 18 to 28 hours and in others within 3 days. A guinea-pig which received a subcutaneous injection of the bouillon culture of the crushed meat died in 48 hours, having shown marked lassitude and profuse diarrhœa. In all cases, section showed enlargement of the spleen, which was bluish-red in color, strong injection of the small intestine, and marked redness of the medullary substance of the kidneys. Cover-glass preparations from the spleen showed fairly long and broad bacilli, and the same were developed on agar from the meat itself.

Poisoning by Horse Meat.—Gaffky and Paak[2] investigated an outbreak in the district of Löwenberg, which was known to involve at least 30 and probably more individuals. The offending materials were horse meat, horse liver, and horse sausage. The patients complained very soon after eating, in one case within a half hour, of nausea, headache, abdominal pain, borborygmus, diarrhœa, dizziness,

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXVIII., p. 484.
[2] Arbeiten aus dem kaiserlichen Gesundheitsamte, VI., p. 159.

trembling, and great thirst. The temperature rose to 104° F. One case terminated fatally. Bacteriological examination revealed a bacillus which differed in some respects from that of Gaertner.

Poisoning by Sausages.—CASE I.—Tripe[1] reported in November, 1879, an outbreak which included 64 out of 66 persons who had eaten of a single batch of sausages. The onset was characterized by vomiting, purging, and dizziness, which came on after intervals of varying length. There was extreme weakness, and many had severe cramps in the legs and pains in the abdomen. In the majority of cases the vomiting and purging lasted from 36 to 48 hours. The discharges were very offensive, and looked like dirty wash-water. There was marked cerebral disturbance, and a sensation of acridity in the throat was common. One of the victims died, but the autopsy revealed nothing unusual beyond a number of red patches in the intestine. The remaining sausages were found to have a tainted and putrid odor.

CASE II.—The "Limmetshausen case." The liver of a healthy pig was made into sausages, which were then smoked for a number of days and hung up. On the eighth day, they were eaten by a family and a number of invited guests, one of whom, objecting to their peculiar taste, refrained from eating and escaped the trouble that came to all the rest. The symptoms, which appeared within a short time, were the same in kind in all, but differed in severity. They included abdominal pain, vomiting, dizziness, dryness of the mouth and throat, and difficult deglutition. The pupils became dilated, and vision was much impaired and finally lost. The muscular and nervous systems were very much affected; the pulse was rapid and weak; respiration became embarrassed, swallowing and speaking impossible. Death ensued in 3 cases, preceded by great lividity of the face and spasms of the extremities.

CASE III.—Van Ermengem[2] relates an instance in which the remaining sausages of a lot which had caused illness in several persons were apparently so wholesome and looked so inviting that the expert and his assistants to whom they were sent ate them and themselves became ill. The expert died on the sixth day, and autopsy showed gastroenteritis, acute nephritis, and fatty degeneration of the liver. Gaertner's *B. enteritidis* was found both in the organs and in the sausages. The latter were made of horse meat.

CASE IV.—Carl Günther[3] reports that, in several places in Posen, a large number of persons were made sick after eating pork sausages and blood, all of which had been supplied by one butcher. The most important symptoms were abdominal pain, vomiting, purging, great weakness, and lassitude. One man of 47 years died after hardly a day's sickness. Günther examined portions of the deceased and also samples of meat and blood found in the house, and sausage and meat

[1] Medical Times and Gazette, Nov. 29, 1879.
[2] Revue d'Hygiène, 1896, p. 761.
[3] Archiv für Hygiene, XXVIII., p. 146.

from the shop of the butcher. From the victim's spleen and liver he isolated *B. enteritidis*, but while a number of species were found in the foods, this bacterium was not detected, perhaps having perished through the influence of the other species present.

CASE V.—This interesting case of poisoning by sausage composed of pork and beef is related by Silberschmidt,[1] and serves as an illustration of the methods commonly employed in the manufacture of sausages. Nearly fifty people were poisoned by eating a kind of sausage known in Switzerland as "Landjäger." It is made of beef, often, also, horse meat with pig fat. The materials are chopped rather coarsely, spiced, put into casings, pressed flat for a day, smoked two days, dried in the air several days more and then eaten in the raw state. The sausages in this instance were made of cow beef from animals that had been certified as sound by a veterinarian, and pork that had been bought about two weeks previously and kept with preservative salt, and had appeared fresh and unchanged when used. In the morning of the first day that the sausages were on sale, a man and his wife ate one of them together, and both were made so sick toward evening and during the night that a physician was called. In the afternoon of the same day, 19 fishermen ate of them, and on the following day it was reported that all of them had been made sick. In the evening, another man ate one, and it pleased him so much that he took one home to his wife and children. On the next day, he had abdominal pains, headache, vomiting, diarrhœa, thirst, and a chill. In the afternoon, his wife and two children who had eaten were similarly seized. A boatman who ate two whole sausages suffered no inconvenience beyond a little pain on the following day. Another, who was sick eighteen days and then returned to his work, was seized again ten days later with the same train of symptoms. One man, aged eighteen years, entered the hospital in the morning of the second day, and died during the night, two days and a half after ingestion of the sausage. At the time of entrance, the abdomen was sensitive and he was passing grayish watery stools; in the afternoon, he was delirious, and his pulse was very small, irregular, and rapid. During the night he collapsed and died. Section after twelve hours showed a spleen of normal size, swollen mesenteric glands, and hyperæmia of the stomach and intestines. The follicles were much swollen, and in the ileum were several areas from 4 to 6 cm. in length by 1 cm. in breadth, where the mucous membrane was discolored and eroded. Other organs were normal. Six others of those affected were discharged from the hospital after from seven to fifteen days' treatment. In an adjoining town, where sausages of the same lot were sold, there were 16 other cases, all with the same symptoms. Taking all the cases together, the symptoms of prominence were as follows: Very severe, partially crampy, abdominal pains; very profuse diarrhœa, the stools numbering from eight to twelve per day, and in color varying between gray, greenish, and yellow; usually vomiting, the rejected matters being

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXX., p. 328.

watery and brownish; sunken eyes, high fever, great lassitude, tenderness over abdomen, cramps in the calves, great thirst, and, occasionally, meteorism. In most of the cases, the symptoms appeared on the day after eating. The duration of the illness ranged between one and thirty days, the greater number recovering in two weeks, and becoming fit for work in three.

As is commonly the case in these outbreaks, the attention of the authorities was not drawn to the matter in either town until some days had elapsed. Chemical analyses of unused sausages were made at both places. One analyst reported negative results; the other reported the presence of ptomains, but did not further particularize. Bacteriological investigation revealed the presence of a variety of organisms, as was to have been anticipated, and among them, especially marked, *Proteus vulgaris*.

Poisoning by Kid Meat.—Hensgen[1] has reported the case of a whole family stricken after eating the meat of a kid which was killed when but a few days old. A twelve year old girl was seized in eleven hours with a chill, followed by fever, dizziness, vomiting, and violent diarrhœa. The temperature rose to 103.6° F. She was confined to her bed for five days. The father, forty-nine years old, was seized with the same symptoms in twelve to thirteen hours, and had also headache, pain in the joints, thirst, and inability to walk. The tongue was dry, the pulse rapid and small, and the pupils reacted slowly. He was sick eight days. The mother, who ate but little, was seized suddenly in the night with vomiting, and such great dizziness that she was unable to walk without holding on to the furniture. A boy, under two years of age, was seized in the night with vomiting and violent diarrhœa, which soon became bloody. The stools were unusually offensive, and persisted so for several days. He was sick nine days. Three other children, who ate but very little, were sick two days with slight abdominal pain and diarrhœa. No material was obtainable for examination. The butcher said that the kid was apparently healthy, but the mother declared that the meat around the joints of the hind legs was very soft and watery, and the joints themselves enlarged (septic polyarthritis?).

Meat Inspection and Slaughtering.

The value and advisability of thorough inspection of meats before they are placed on sale are universally conceded. In this country, under the inspection law of March 3, 1891, all meat intended for export is required to pass a very strict system of inspection. The animals are inspected before being slaughtered, and their carcasses are examined microscopically by officials of the Bureau of Animal Industry before being packed. The inspection of meat for local consumption is wholly a matter of local authority; some States have inspection laws and others have none; many cities have special regulations which are enforced by officials who may or may not be competent through

[1] Zeitschrift für Fleisch- und Milchhygiene, VIII., p. 181.

proper training. In Germany, the system of inspection is very rigid, particularly in the case of meats from foreign countries. This is due very largely to the activity of the agricultural interests in protecting themselves from outside competition; and under the benevolent plea of protecting the health of meat consumers, much care and attention are given to hunting for excuses for excluding American meats which have already been inspected.

The Federal meat inspection service is, according to Salmon,[1] a sanitary rather than a commercial inspection, applied not alone to meats for export, but also to those intended for inter-state commerce. Curiously, however, the very important inspection for trichinæ is primarily a commercial matter, being applied only to pork intended for shipment to certain foreign countries which require it.

The United States inspectors are instructed to condemn all female animals in an advanced stage of gestation, and to prevent their slaughter for food, Salmon ruling that, though "the animal is, strictly speaking, in a physiologic condition, it is not in its usual physiologic condition, nor is the change one which is calculated to improve the quality of the meat." Females in which parturition has recently occurred are likewise condemned as unfit for food. Many animals are condemned on account of bruises and injuries received on their way to market; during 1900, there were condemned for this cause, in round numbers, carcasses or parts of carcasses of 4500 cattle, 1,000 sheep, and 12,300 hogs. In some of these, the injuries were extensive, sometimes complicated with abscesses, septic infection, and gangrene.

The cattle diseases most prominent as causes of condemnation are tuberculosis, actinomycosis, and anæmia; next in order are septicæmia, pneumonia, peritonitis, pyæmia, icterus, abscesses, and Texas fever. In swine, the most common diseases are hog cholera, swine plague, tuberculosis, icterus, pyæmia, abscesses, pneumonia, inflammations of the abdominal cavity, septicæmia, and tumors. The most common causes of condemnation of sheep are anæmia and emaciation, bruises and injuries, tuberculosis, abscesses, pneumonia, uræmia, septicæmia, icterus, and pyæmia.

In by no means every case is the entire carcass of an animal afflicted with tuberculosis or actinomycosis condemned, since, in the early stages, both diseases usually are localized, and the carcass as a whole not affected. A tuberculous animal is condemned wholly when there is emaciation or generalization of the lesions, and "when the lesions in any organ or organs are of such number and size as to indicate that the system at large may have been affected, either by inflammation, by the mixed infection, by the secretion and absorption of pus or toxic principles, or by interference with the general nutrition of the body" (Salmon). In nine years of Federal meat inspection, the condemnations per 10,000 animals, were, according to Salmon,[2] as follows: cattle, 0.48; sheep, 8.1; swine, 37.

[1] Journal of the American Medical Association, Dec. 28, 1901, p. 1715.
[2] Ibidem, March 30, 1901.

In inspecting meats, special attention should be paid to the connective tissue and glandular organs. The odor of a carcass should be sweet, and the meat should communicate no unpleasant smell to a wooden skewer thrust into it and withdrawn. The muscle should be firm and elastic, but not tough. Any variation from the natural color should be regarded with suspicion, very dark color suggesting febrile condition, or that the animal was not slaughtered, or was slaughtered in a dying condition. Such meat undergoes decomposition much more rapidly than normal meat. Animals that have been drowned or have been killed by accident without being bled yield a dark and discolored meat that is likely to decompose more rapidly than that of animals that have regularly been slaughtered, but an animal that has been injured, but not killed, may be slaughtered, properly bled and dressed, and its meat is then perfectly good.

Animals should be kept without food for at least twelve hours before slaughter, and the carcasses should be hung for a number of hours to cool. Many diseases are indicated more clearly after the body has cooled.

The Jewish method of slaughtering is regarded by many as far superior to any other. According to Dembo,[1] it is the most rational from a hygienic standpoint, since the animal is bled rapidly and completely, and the convulsive movements cause the meat to be more tender and of more attractive appearance. Lactic acid is developed, and through its chemical action on potassium phosphate, potassium lactate and acid phosphate of potassium are formed. The latter hinders the development of micro-organisms, delays the formation of ptomains and other poisonous matters, and improves the taste. Rigor mortis comes on more quickly, and the meat is, therefore, more quickly available for use, and also will keep several days longer than ordinarily.

A process of slaughtering originating in Denmark appears to have borne the test of a hard three-months' trial in a very satisfactory manner, and recommends itself for adoption in the tropics, where meats decompose with exceeding rapidity. The animal is shot in the forehead and killed or stunned, and as it falls, an incision is made over the heart and the ventricle is opened for two purposes: to allow the blood to escape, and to admit of the injection of a solution of salt through the bloodvessels by the aid of a powerful syringe. The process requires but a few minutes, and the carcass may be cut up at once.

EGGS.

Eggs form a valuable substitute for meats, being fairly rich in fats and proteids, and are well adapted to the stomach of the invalid and convalescent when meats cannot be borne. The nutritive part of the white is practically limited to proteids, which amount to about 12 per cent.; the yolk is richer in proteids, and contains in addition about 33

[1] Deutsche Vierteljahrschrift für öffentliche Gesundheitspflege, XXVI., p. 688.

per cent. of fat. The albumin of the white is in a condition of solution in cells with very thin walls. The fatty matters of the yolk are in a condition of emulsion, being held in suspension by the vitellin. The entire yolk is held together by an enveloping membrane and is suspended in the white, being held in position by an albuminous band at either end:

The following table by Langworthy[1] shows the average composition of eggs of different sorts:

	Refuse.	Water.	Protein.	Fat.	Ash.	Fuel value per pound.
Hen:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
Whole egg as purchased	11.2	65.5	11.9	9.3	0.9	635
Whole egg, edible portion	...	73.7	13.4	10.5	1.0	720
White	...	86.2	12.3	.2	.6	250
Yolk	...	49.5	15.7	33.3	1.1	1,705
Whole egg boiled, edible portion	...	73.3	13.2	12.0	.8	765
White-shelled eggs as purchased	10.7	65.6	11.8	10.8	.6	675
Brown-shelled eggs as purchased	10.9	64.8	11.9	11.2	.7	695
Duck:						
Whole egg as purchased	13.7	60.8	12.1	12.5	.8	750
Whole egg, edible portion	...	70.5	13.3	14.5	1.0	860
White	...	87.0	11.1	.03	.8	210
Yolk	...	45.8	16.8	36.2	1.2	1,840
Goose:						
Whole egg as purchased	14.2	59.7	12.9	12.3	.9	760
Whole egg, edible portion	...	69.5	13.8	14.4	1.0	865
White	...	86.3	11.6	.02	.8	215
Yolk	...	44.1	17.3	36.2	1.3	1,850
Turkey:						
Whole egg as purchased	13.8	63.5	12.2	9.7	.8	635
Whole egg, edible portion	...	73.7	13.4	11.2	.9	720
White	...	86.7	11.5	.03	.8	215
Yolk	...	48.3	17.4	32.9	1.2	1,710
Guinea fowl:						
Whole egg as purchased	16.9	60.5	11.9	9.9	.8	640
Whole egg, edible portion	...	72.8	13.5	12.0	.9	755
White	...	86.6	11.6	.03	.8	215
Yolk	...	49.7	16.7	31.8	1.2	1,655
Plover:						
Whole egg as purchased	9.6	67.3	9.7	10.6	.9	625
Whole egg, edible portion	...	74.4	10.7	11.7	1.0	695
Evaporated hens' eggs	...	6.4	46.9	36.0	3.6	2525

The proteids of eggs have been studied by Osborne and Campbell,[2] who found that the yolk contains a large amount of protein which resembles a globulin, but is believed to be a mixture of compounds of protein matter with lecithin. The proteids of the white were found to include ovalbumin, ovomucin, ovomucoid, and conalbumin.

Eggs contain a certain amount of sulphur, to which the staining of silver spoons and the odor of rotten eggs (hydrogen sulphide) are due. The rotting of eggs is supposed to be due to the admission of fermentative micro-organisms through the pores of the shell, or to those already present before the shell is formed.

It is a commonly accepted idea in some parts of the country that eggs with brown shells are of greater richness than others, and that the degree of richness is directly proportionate to the depth of color. In some markets, on the other hand, the white egg is held in higher esteem.

[1] U. S. Department of Agriculture, Farmers' Bulletin, No. 128 (1901).
[2] Report of Connecticut Experiment Station, 1899, p. 339.

According to the results of an extensive study of the chemical composition of eggs carried on at the California Experiment Station mainly for the purpose of determining what differences, if any, exist between them, there is no basis of fact for the popular belief. In fact, the very slight differences noted were in favor of the white eggs, but the average differences between the two kinds were less than the fluctuations between individual specimens of the same group. The figures obtained are presented in the following table taken from Farmers' Bulletin No. 87 :[1]

ANALYSIS OF BROWN-SHELLED AND WHITE-SHELLED EGGS.

	Water.	Protein.	Fat.	Ash.	Shell.	Total.
Brown-shelled eggs:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Yolk	49.59	15.58	33.52	1.04	. .	99.73
White	86.60	11.99	.21	.54	. .	99.34
Entire egg	65.57	11.84	10.77	.64	10.70	99.52
White-shelled eggs:						
Yolk	49.81	15.49	33.34	1.05	. .	99.69
White	86.37	12.14	.35	.56	. .	99.42
Entire egg	64.79	11.92	11.22	.67	10.92	99.52

The question of influence of breed on composition has been investigated at the Michigan Experiment Station. The results showed that the variations in composition are too slight to be of practical value, and, as with the brown and the white eggs, so slight as to be less than the variations between individual specimens from the same breed. The influence of the nature of the feed was investigated also, and was found to be of little or no importance.

The flavor of eggs varies according to age, those which are perfectly fresh having the finest flavor. It is dependent also, to some extent, upon the nature of the food consumed by the fowl, the best coming from a purely grain feed. A very nitrogenous feed causes a more or less disagreeable flavor and odor. The influence of highly flavored feed has been studied by Emery,[2] who fed hens with a ration containing wild onion tops and bulbs. After fifteen days, the eggs having no unusual taste, each hen received daily one ounce of this addition instead of a half ounce as before, and in three days the eggs were flavored so strongly as to be repugnant to the taste.

The iron content of the yolk of eggs is said by Schmidt[3] to be increased materially by feeding saccharate of iron to hens. He asserts, also, that the iron so incorporated is more assimilable than most iron preparations given in the anæmic condition. Aufsberg[4] asserts that by feeding certain iron compounds, the iron content can be increased eight times.

The digestibility of eggs has been studied at the Minnesota Experi-

[1] Government Printing Office, Washington, 1899, p. 24.
[2] Bulletin 167, North Carolina Experiment Station.
[3] Zeitschrift für angewandte Chemie, 1900, p. 705.
[4] Pharmaceutische Zeitung, 1900, p. 366.

ment Station.[1] It was shown that, while the method of cooking has some effect on the rate of digestion, the total digestibility is not affected. Eggs boiled three, five, and twenty minutes, and digested for five hours with pepsin solution, showed at the expiration of that time respectively 8.3, 3.9, and 4.1 per cent. of undigested proteids. Cooked for five and ten minutes in water at 180° F. and similarly treated, they left no undigested residuum.

LARD.

Lard is the semi-solid fat of the slaughtered hog, separated from the tissues by the aid of heat. According to the parts from which it is derived, it is classified as follows: (1) Neutral lard. This is derived from the fresh leaf, which is reduced to a pulp after being cooled, and then rendered in the kettle. A part of the fat is separated at from 105° to 120° F., and the residue is sent to the rendering tanks for further treatment. The lard obtained is washed, while hot, with water containing a trace of sodium carbonate, common salt, or dilute acid. (2) Leaf lard. This is obtained from the residue above mentioned, which is subjected to steam heat under pressure. (3) Choice kettle rendered lard. This is obtained from the remaining portions of the leaf together with the fat from the backs. Both the leaf and back fat are passed first through a pulping machine. (4) Prime steam lard. This is made from the head, the fat of the small intestine, trimmings, and other fatty parts.

The spleen, pancreas, trachea, and all other refuse parts and trimmings, with the exception of the small intestine, the liver, lungs, and part of the heart, go into the rendering-kettle for what fat there may be in them, and the product is variously, but not graphically, designated.

"Refined lard" is a term used to designate a lard composed chiefly of cotton oil and stearin. It is known more often as "lard compound."

Physical and Chemical Properties of Lard.—At 40° F., the specific gravity is 0.890; at 100°, about 0.860; it differs not very materially from that of the substances used as adulterants, excepting cotton-seed oil, which is notably heavier. The melting-point ranges from 39.1° to 44.9° C. (102.4° to 112.8° F.), according to the part of the carcass from which the fat is derived, and hence it cannot be taken as a safe guide in the determination of purity.

Pure lard, melted, and mixed with strong sulphuric or nitric acid, will give only a slight color, which may be yellowish, pinkish, or inclined to light brownish. Cotton-seed oil and other seed oils, and mixtures containing them, similarly treated, yield any color between yellowish brown and very brownish black or even black. The refractive index of pure lard is materially lower than that of cotton-seed oil.

Pure lard contains only traces of volatile fatty acids, 5 grams yield-

[1] Farmers' Bulletin No. 87, Government Printing Office, Washington, 1899, p. 25.

ing an amount which is neutralized by $\frac{1}{5}$ or $\frac{2}{5}$ of a cc. of decinormal sodium hydrate solution. The non-volatile fatty acids are present to the extent of about 95 per cent. The iodine absorption number varies according to the part of the carcass from which the fat is derived, but averages about 60. The iodine number of cotton-seed oil is about 109, and that of stearin is approximately 20. Thus, these substances used as adulterants may be mixed in such proportion as to yield the normal iodine number of lard.

With nitrate of silver solution, pure lard causes no more than the very slightest amount of reduction, and generally none at all; but cotton-seed oil causes a very marked reduction of the salt to the metallic state, with the result that the mixture has a brownish or black appearance from the minute black particles formed.

A small amount of lard, dissolved in a mixture of equal parts of alcohol and strong ether in a test-tube and allowed to stand in a cool place, will, when the solvent in large part is evaporated, show masses of crystals, which, on examination under the microscope, are seen to be rhombic and extremely variable in size. Beef stearin, similarly treated, shows fan-shaped and dumbbell-shaped clusters of needle crystals. Mixtures of pure lard and beef stearin will show both forms of crystals. Sometimes, when crystallization proceeds rapidly, the crystals from pure lard are extremely small, and are clustered in such a way as to be distinguished from beef stearin crystals only with great difficulty. It is essential that the crystallizing process shall proceed slowly, and that the amount of lard dissolved in half a test-tube of the solvent shall be quite small—not larger than a large pea. The mouth of the test-tube should be stopped with cotton.

Section 3. MILK AND MILK PRODUCTS.

MILK.

Milk is a solution of sugar, mineral matter, and proteids, with other proteids and fat in suspension. Its composition is very variable, not alone as between different species of mammalia by which it is produced, but as between different individuals of the same species. Of the domestic animals, the ass and mare produce milk which most closely approximates that of woman in composition, but our chief interest in milk as an article of food in general use lies in that produced by cows and, to a certain extent, in that of goats, which is very similar in composition. While the composition of milk of other animals than those already mentioned can have for most of us merely a scientific interest, it may be of some practical utility in the management of breast-milk to bear in mind that the milk of animals whose diet is largely or chiefly meat is richest in those elements, the proteids, that are most commonly at the bottom of digestive disturbances in breast-fed children.

Composition of Cows' Milk.—The composition of milk of average good quality may be expressed fairly in round numbers as follows:

Fat	4.00
Sugar	5.00
Proteids	3.30
Mineral matter	0.70
Total solids	13.00
Water	87.00
	100.00

According to Vieth, the average composition of more than 120,000 samples analyzed in England was:

Fat	4.10
Solids not fat	8.80
Total solids	12.90
Water	87.10
	100.00

The average of a large number of analyses made in this country showed:[1]

Fat	4.00
Sugar	4.95
Proteids	3.30
Mineral matter	0.75
Total solids	13.00
Water	87.00
	100.00

The milk yielded by 426 cows from private farms in Massachusetts, and by 175 more belonging to public institutions, was analyzed by the author and his associates, and found to give the following results:[2]

426 cows from private farms, total solids	13.36
175 cows from public institutions, total solids	13.00
601 cows (both classes), total solids	13.26

Fat.—The fat of milk exists in very minute globules which vary widely in size, the largest being between six and seven times larger than the smallest, but the latter are most abundant. Whether or not they have an albuminous envelope, is a matter of doubt, the evidence for and against being about equal, and of no great importance.

It consists of glycerides of ten different fatty acids, five of which belong to the non-volatile and five to the volatile class. The glycerides of the former group constitute by far the greater part. They are stearin, palmitin, olein, myristin, and butin; the two last are present in very minute amounts. Those of the latter group give the characteristic butter flavor. They are butyrin, caproin, caprylin, caprin, and laurin; the two first are the important ones, and together amount to over 7 per cent. of the whole fat; the three others are present in but insignificant traces.

[1] American Experiment Station Record, V., No. 10.

[2] The detailed analyses, with data as to breed, nature, and amount of feed, etc., can be found in the pamphlet issued by the State Board of Health: Results of Inquiries Relative to the Quality of Milk as Produced in Massachusetts. Boston: February, 1887.

The fat, being the lightest part of milk, tends to rise to the surface when the milk is allowed to stand, and then forms a layer which we know as cream. This contains not fat alone, but all of the constituents of the milk, and is, therefore, simply milk containing an excessive amount of fat.

It is a common error to regard the depth of the cream layer which forms on standing a given length of time as an infallible measure of the richness of the milk by which it is yielded; but cream does not always rise well in rich milk, even after standing more than twenty-four hours. The author repeatedly has found the percentage of cream thrown up by a specimen of milk in a 100 cc. graduate in twenty-four hours, as measured by the lines of graduation, to be less than the actual percentage of fat as shown by analysis. The rapidity with which the fat finds its way to the surface depends largely upon the size of the fat globules. The largest rise first, and the very smallest may not rise at all. Again, a watered milk throws up its fat more quickly than a normal specimen, although it does not contain as much. It appears, therefore, that a milk of inferior grade may under some circumstances show a deeper cream layer than a milk of unusual richness. Generally speaking, however, a rich milk will usually show its quality on standing.

The first part of a milking is always poor in fat, the middle portion contains about the average amount of the whole, and the last portion is always the richest. The first portion is known as "fore-milk," the last as "strippings." A specimen of "strippings," analyzed by the author, gave the following results:

Fat	9.82
Sugar	4.00
Proteids	4.21
Ash	0.79
Total solids	18.82
Water	81.18
	100.00

Milk-sugar.—Lactose or sugar of milk, is peculiar to milk. It is much less soluble in water than dextrose and sucrose. Heated to 100°–131° C., it becomes changed in color to brownish, and at higher temperatures loses water of crystallization and undergoes further change. At 175° C., lactocaramel is formed. When heated in solution, in milk itself, for example, it begins to undergo decomposition changes at 70° C. and above. Through the action of the lactic ferments, it gives rise to lactic acid. In the polariscope, it is dextrorotary.

Proteids.—The greater part of the proteids of milk, about 80 per cent., is casein, or, as it is called sometimes, caseinogen. It contains both sulphur and phosphorus, and is in intimate combination with calcium phosphate. It is not coagulated by heat, but is precipitated by acids, by which the combination is broken up. In the presence of lactic acid in small amounts, due to the breaking up of lactose, coagulation is hastened by the application of gentle heat. This phenomenon

is observed very commonly in the case of milk which to the taste is apparently sweet, but which is "just on the turn."

The chief part of the remainder of the proteids is lactalbumin. This is coagulated by heating to 65°–73° C., but not by dilute acids. It contains sulphur, but no phosphorus. In amount it ranges from 0.2 to 0.8 per cent. It is much more abundant in colostrum. The remaining proteids are lactoglobulin, which is coagulated by heat; lactoprotein, coagulable by neither heat nor dilute acids, and fibrin. Each exists in but very small amounts.

Mineral Matter.—The mineral matter contained in milk consists of phosphates and chlorides of potassium, sodium, calcium, and magnesium, and extremely minute traces of iron. Of the bases, potassium is the most abundant, with calcium, sodium, and magnesium in the order given. The phosphates predominate over the chlorides. Part of the calcium exists in combination as phosphate with the casein, and the rest, according to Danilewsky,[1] as mono- and tricalcium phosphate and in combination with citric acid. Part of the magnesium, also, exists in combination with citric and other organic acids. In very small amounts, these are normal constituents of milk of various animals. In human milk, citric acid is present to the extent of about 0.05 per cent., and in cows' milk, it is about three times as abundant.

Specific Gravity.—The specific gravity of cows' milk of normal composition ranges from 1.029 to 1.034. It increases very slightly for about five hours after the milk is drawn, and then becomes stationary. The increase is believed to be due to molecular modification of the casein, and not to the escape of gases. It is lowered by fat and water, and by the presence of bubbles of air, and is raised by removal of cream.

Reaction.—When freshly drawn, milk shows the so-called amphoteric reaction; that is, it is acid to litmus and alkaline to turmeric. The alkaline reaction is intensified on warming, but the acid reaction is not influenced thereby. On standing, the alkaline reaction is overcome by the lactic acid which is formed gradually from the sugar, and the acid reaction is increased in consequence of the same. The original acid reaction is due to the presence of phosphates, the alkaline to alkaline carbonates. Human milk is normally alkaline, and that of carnivora is acid.

Appearance.—The appearance of normal milk is too familiar to need description; but under certain rare abnormal conditions, milk may assume different colors, including blue, yellow, violet, and red. These changes of color are due to the action of certain bacteria, and are always evidence of unsanitary conditions to which the milk is exposed at the dairy or during distribution and storage.

Blue milk is due to the action of *B. cyanogenes*, which produces a blue color in no other food material. For its development it requires the presence of lactic ferments, and, therefore, has no effect on milk that is sterile. Another organism capable of producing the same effect is *B. cyaneofluorescens*.

[1] Wratsch, 1901, p. 549.

A red color may be caused by *B. prodigiosus* or *B. lactis erythrogenes*, sometimes by blood, and, it is said, by madder and other red coloring-matter in the feed. Yellow is caused by *B. synxanthus*, and violet by *B. violaceus*.

All of these abnormal milks are, aside from their uninviting appearance, unfit for food, since they are likely to cause gastro-intestinal irritation. Thus Eichert[1] records a case of severe diarrhœa, with very offensive stools, in a child of nine months, which was due to red milk caused by a bacillus (probably *B. lactis erythrogenes*) present in the milk ducts at the time of milking.

Another abnormal condition caused by a large variety of organisms is characterized by alteration of the natural consistence to one of sliminess, which appears only some hours after the milk is drawn. Slimy or "ropy" milk throws up no cream, and cannot be churned, but although it is most repugnant to the senses, it causes no digestive disturbances if ingested. In three specimens of ropy milk from as many different creameries in the State of New York, Ward[2] found the change due to *B. lactis viscosus* (Adametz).

Taste.—The flavor of milk is modified very sensibly by the character of the feed and by the absorption of gases and volatile matters of all kinds. It is affected very readily by turnips, garlic, wild onion, mouldy hay and grain, distillery swill, and damaged, rotten ensilage.

Bitterness of taste may be due either to some constituent of the feed or to bacteria. When due to feed, the taste is bitter from the very first, but when caused by bacterial agency it develops some time after milking, when the organisms which produce it have had the opportunity to act upon the proteids or whatever constituent may be concerned. It may be due also to inflammatory conditions of the udder, in which case it may or may not be noticeable when the milk is freshly drawn. The bacteria concerned in producing bitterness may exist in the ducts of the teats, or may come from stable filth. Damman[3] mentions a case in which the persistently bitter taste disappeared after the floor of the stable was cleaned and disinfected, and the ducts of the teats syringed out with disinfectant solution. Strong-smelling disinfectants may not be used in dairies because of the readiness with which milk absorbs odors. This absorptive capacity is so well recognized that milk is stored commonly in separate compartments of refrigerators, away from foods which evolve distinct odors.

Presence of Alcohol.—Distillery swill not only causes a decidedly bad flavor, but may, in addition, and contrary to a generally accepted idea, cause an alcoholic milk. Thus, according to H. W. Weller,[4] a sample of milk derived from cows fed on distillery refuse containing 5.90 per cent. of alcohol yielded in addition to a high proportion of milk solids, 0.96 per cent. by weight of alcohol. The milk was com-

[1] Zeitschrift für Fleisch- und Milchhygiene VIII., No. 5.
[2] Science, 1901, No. 322, p. 324.
[3] Deutsche thierärztliche Wochenschrift, 1897, No. 1.
[4] Forschungsberichte über Lebensmittel, etc., 1897, p. 206.

plained of on account of an unpleasant after-taste. Teichert[1] records a case in which calves and lambs failed to thrive, and many died from a form of diarrhœa. The mothers were fed on distillery waste, and yielded milk containing alcohol. That alcohol or something connected therewith may be eliminated in milk, is shown by numerous cases, among which are the following: Vallin[2] records that a nursing infant was seized with convulsions with great regularity on Mondays and Thursdays, but was quite well on other days. Investigation showed that the wet-nurse on Sundays and Wednesdays, her "days out," was in the habit of drinking freely of alcoholics. The curtailment of the privilege was followed by disappearance of the difficulty. Farez[3] cites 2 cases which show the bad influence of alcohol on nursing children. In one, the wet-nurse drank wine at meals, and especially in the evening, and the child never ceased fretting, crying, and screaming from 9 o'clock until 11. The nurse complained bitterly of the naughtiness of the child, and was grieved at the suggestion that she was herself at fault through drinking too much, but she was induced to abstain from alcohol entirely, and from that time there was no further trouble. In the other case, the mother drank tea at noon and wine at dinner, and the child was quiet during the afternoon, but screamed and fretted all the evening and until midnight. A change to wine at noon and tea at dinner produced a corresponding change in the behavior of the child, the turbulent period occurring in the afternoon. When the mother eliminated wine from her dietary entirely, the trouble ceased.

Colostrum.—The milk secreted before and in the early stage of lactation is known as colostrum. It is a yellow, somewhat viscid fluid of strong odor and acid reaction. In composition, it differs very materially from milk, particularly in its percentage of proteids. It contains, sometimes, so large a percentage of lactalbumin and lactoglobulin that it is coagulated by boiling. Its content of casein is about normal, but it is not coagulated by rennet, or at most imperfectly. In the early stages, its sugar is dextrose and not lactose. According to Tiemann,[4] it ranges in specific gravity from 1.0299 to 1.0594, in fat from 0.56 to 9.28, in proteids from 4.66 to 21.78, in ash from 0.82 to 1.25, and in total solids from 12.93 to 32.93. Under the microscope, it shows large corpuscles, known as colostrum corpuscles, which disappear within two weeks at most after the time of calving.

Changes Produced in Milk by Boiling.—Boiling causes greater coalescence of the fat globules, changes in the character of the sugar, coagulation of lactalbumin, and destruction of micro-organisms and ferments. Boiled milk, therefore, will keep better than raw milk. The scum which forms on the surface is largely fat, casein, and lactalbumin, and occurs in consequence of rapid evaporation at that point. Boiled milk is digested slightly less readily than raw milk, and sour

[1] Milch Zeitung 1901, p. 148.
[2] Revue d'Hygiène, 1896, p. 953.
[3] Tribune médicale, June 20, 1900, p. 488.
[4] Zeitschrift für physiologische Chemie, 1898, p. 363.

milk is digested more readily than either; but boiled milk, as will be noted later (see page 92), is not always a desirable food for young infants, on account of its changed character. The question whether or not a given milk has been boiled may readily be determined by the application of simple tests (see Analysis of Milk).

Changes Due to Bacterial Action.—At ordinary temperatures, milk soon begins to undergo changes initiated and carried along by various species of micro-organisms which exist in the ducts of the teats or fall into the pail from the external surface of the udder or surrounding parts, or from the air, or from the hands and clothes of the milker, or which are already present in the pail or other vessel into which the milk is received. The most common change is brought about by the lactic ferments, of which more than a hundred species have already been identified. They attack the milk-sugar and cause the formation of lactic acid, which, on accumulating in sufficient amount, causes the milk to curdle. Their multiplication proceeds most rapidly at temperatures ranging from 25° to 30° C. Therefore, in order to inhibit their action as far as possible, milk should be cooled without delay and kept in storage at low temperature. In addition to the lactic ferments, there are others which are known as casein ferments. These produce a substance much like rennet in its action. They may act in the absence of the lactic ferments, and then their action is accompanied by the development of alkalinity.

Under certain conditions, in addition to changes in taste, color, and consistency already noted, intensely poisonous benzene derivatives are formed, the most important of which, diazobenzene, called by its discoverer, Professor V. C. Vaughan, tyrotoxicon, is the exciting cause of the train of symptoms commonly known as milk poisoning, cheese poisoning, and ice-cream poisoning.

A number of other organisms constitute the group of so-called butyric ferments, many of which are of the class of casein ferments. They cause the production of butyric acid in the decomposition of proteids.

In consequence of the action of the various species of organisms, it is important that bacteria in general should be excluded as completely as possible from milk by the observance of the utmost cleanliness in milking, handling, and storing. The milk of cows stalled in badly ventilated, unclean stables, and of cows with unclean udders, will decompose much more rapidly than that of cows kept under better sanitary conditions. Even when the cow and her surroundings are kept in a cleanly state, the very first part of a milking should be rejected, on account of the very large numbers of bacteria present in the ducts of the teats. Under even the best of conditions, many bacteria are present in freshly drawn milk, and these increase rapidly in number unless killed by the action of heat or other germicides. Indeed, it has been found impossible in the majority of experiments to obtain sterile milk even when the greatest precautions have been observed to exclude extraneous organisms.

The first part of a milking is richest in bacteria, because those which

have multiplied within the ducts of the teats since the previous milking are expelled mostly with the fore-milk, but even the very last portions of the strippings may contain as many as 500 bacteria per cc. Thus, Schultz[1] found in the first portions of cows' milk 97,240 per cc., in the strippings 500, and in goats' milk 78,718 and 665. For the attainment of the best results as to keeping qualities, all dirt should be brushed from the cow before milking, and the udder and flank should be dampened, in order that dust, fine dirt, and bacteria may be retained *in situ*, and not fall into the milk-pail, which should always be perfectly clean before use.

The difference in the number of bacteria which fall into milk when proper precautions are observed and when they are neglected is very considerable. Thus, Soxhlet found that the milk of a cow with a dirty udder, stalled in a dirty stable, kept sweet 50 hours at ordinary temperature, and that, when her udder was washed and she was milked in the open air, it remained sweet a day and a half longer. Still more instructive are the results obtained by Freeman,[2] who exposed plates, 3.5 inches in diameter, for two minutes as follows: one in the open air, one inside a barn, and a third in front of the milk pail under a cow in the same barn while being milked. The first plate showed 6, the second 111, and the third 1,800 colonies. Such a number of bacteria, falling upon so small a surface within so short a time, is an index of the enormous number which may fall into a pail during the time required for a complete milking.

The enormous number of bacteria which may be commonly present in ordinary market milk, the great influence thereon of non-observance of the strictest cleanliness, and the extreme rapidity of multiplication under favoring conditions, are shown in most striking manner by W. H. Park,[3] who exposes the inexcusable lack of cleanliness in the methods of procuring milk, and of care in cooling, and in keeping it during transportation to the city. Milk from individual cows, where every reasonable means was taken to insure cleanliness, yielded an average of 6,000 bacteria per cc. when 5 hours old, and kept at 45° F., to which temperature it was cooled soon after it was drawn. After 24 hours, the average number fell to 1,933; after 48, it increased to 17,816. Milk taken in winter in well-ventilated, fairly clean, but dusty, barns, and cooled within 2 hours to 45° F., the visible dirt having been cleaned off the hair about the udder, the milkers' hands wiped off, but not washed, the pails and cans clean, but the straining cloths dusty, yielded the following average figures: At time of milking, 15,500; after 24 hours, 21,666; after 48 hours, 76,000. Milk taken from cows kept in ordinary barns, the conditions as to cleanliness of surroundings and method of milking being about what obtain on the average farm, yielded the following average figures:

[1] Archiv für Hygiene, XIV., p. 260.
[2] Medical Record, March 8, 1896.
[3] Journal of Hygiene, July, 1901, p. 391.

	Winter.	Summer.
Shortly after milking	16,650	30,366
After 24 hours	31,000	48,000
After 48 hours	210,000	680,000

Twenty samples of average milk taken immediately on arrival in the city, much of it having been transported more than 200 miles, yielded from 52,000 to 35,200,000 bacteria per cc. (average, 5,669,-850). The average temperature of the samples when taken from the cans was 45° F. Milk as sold in the shops during the morning hours yielded the following averages:

From tenement districts, mid-winter	(13 samples)	1,977,692
From well-to-do " "	(10 ")	327,500
From tenement " September	(5 ")	15,163,600
From well-to-do " "	(5 ")	1,061,400

Concerning the influence of temperature upon the rapidity of bacterial multiplication in milk, it is noted that milk which is rapidly and sufficiently cooled keeps almost unaltered for 36 hours, while if insufficiently cooled, it deteriorates rapidly. The majority of milk bacteria grow best at temperatures above 70° F., but two-thirds of the species isolated will develop good growth at 39° F. at the end of 7 days. They increase slowly after the germicidal properties of the milk have disappeared, and when the organisms have become accustomed to the low temperatures.

The influence of different temperatures on the rapidity of bacterial multiplication is well shown by the results obtained on allowing portions of the same specimen to stand under otherwise similar conditions. At temperatures below 50° F., there was at the end of 24 hours no increase—in fact, a decrease—in the number of bacteria; but at higher temperatures, the multiplication was enormous. The original number per cc. was 3000, and the growths at the several temperatures above 55° F. were as follows at the end of 24 and 48 hours:

Temperature.	24 hours.	48 hours.
60° F.,	180,000	28,000,000
68°	450,000	25,000,000,000
86°	1,400,000,000	
94°	25,000,000,000	

Milk of fair quality from a shop was kept at 90° F. for 8 hours, during which time its contained bacteria increased from 92,000 to 6,800,000 per cc.; another, of poor quality, under the same conditions, showed an increase from 2,600,000 to 124,000,000.

Such growths of bacteria in milk intended for human use can in no way improve the milk, but must seriously affect its wholesomeness. To avoid them, the means are simple: cleanliness everywhere and low temperatures; cleanliness of the cows' exterior, of the stable, of the milkers and their clothing, of all vessels employed—milk pails, pans, bottles, etc.—and of the places where the milk is stored.

Preservation of Milk.—The keeping quality of milk is influenced by cold, which retards the growth and multiplication of bacteria which bring about decomposition; by heat, which destroys them; and by preservatives, which either kill them or retard their growth. Preservation by cold is in many respects preferable to either of the other methods. The constituents are in no way altered in character, there is no change in digestibility, and no element is introduced into the system with the milk to exert any harmful influence upon the digestive processes. In places where ice is expensive or not obtainable, this method is not available, but where it is cheap and plentiful, it is the one in most common use. In some parts of Europe, milk is frozen into solid blocks by the ammonia process, and shipped in that form to market. A large part of the milk supply of Copenhagen is received from a distance in large air-tight cans, into each of which a block of frozen milk, weighing about 25 pounds, is placed, to keep the milk in which it floats at a low temperature.

Preservation by heat includes pasteurization and sterilization. In pasteurization, the whole bulk of the milk is heated to not over 158° F., maintained at that temperature for 10 or 15 minutes, and then cooled rapidly in order to preserve the fresh flavor and prevent the multiplication of such of the bacteria as survive. The length of time required for the destruction of bacteria varies with the temperature employed. Thus, about 70 per cent. of saprophytic bacteria are killed in an hour at 140° F., in 15 minutes at 150°, in 10 minutes at 158°, in 5 minutes at 176°, in 2 minutes at 194°, and in 1 minute at 203°. It is essential that all apparatus and vessels used in cooling and storing shall be clean and sterile. This process is quite sufficient for all practical purposes and hygienic requirements, unless the milk is to be kept for a longer time than usual, in which case it should be repeated at the end of 24 hours. Temperatures higher than 158° F. cause the milk to acquire a cooked flavor, which to many persons is disagreeable.

According to H. Bitter,[1] all pathogenic bacteria in milk are killed with absolute certainty by exposure to 154.4° F. for a half hour, and the milk is altered thereby in neither appearance nor taste. Under ordinary circumstances 20 minutes' exposure is quite sufficient. Some authorities assert that temperatures of 140° to 147° F. are sufficiently high for the purpose, but Professor Theobald Smith[2] has shown that, while tubercle bacilli are destroyed within 20 minutes at 140° F., the formation of a surface pellicle into which they are carried by fat globules shields them from the heat, so that they may survive an exposure of over an hour to 149° F. It is asserted by Morgenroth[3] that at least 30 minutes' exposure to 158° F. is necessary to kill all of the bacilli, but that the same result can be attained at a much lower temperature (131° F.) in 3 hours' heating in a thermophore. It has

[1] Zeitschrift für Hygiene, VIII., p. 240.
[2] Journal of Experimental Medicine, 1899, p. 217.
[3] Hygienische Rundschau, Sept. 15, 1900, p. 865.

been asserted also by M. Beck[1] that 158° F., and even 176° F., are not sufficiently high, even when maintained 30 minutes, for the destruction of all the tubercle bacilli in milk intentionally infected. He heated such milk for 30 minutes at both of the above temperatures, and then injected it into 15 guinea-pigs, all of which became tuberculous after 5 to 8 weeks. But Levy and Bruns,[2] after experimenting with milk enclosed in flasks placed in a water-bath, found that, so far as the tubercle bacillus is concerned, milk is sterilized after 15 to 25 minutes' exposure to 149°–158° F. It seems probable, on the whole, that the widely divergent results of various experimenters have been due to differences in manipulation and in physical conditions.

All the lactic ferments are destroyed very easily, but some of the casein ferments are very resistant, and their spores still more so, and are not killed by boiling for a number of hours; and it is to the presence of these hardy varieties that the difficulty of complete sterilization is due.

Sterilization requires continuous heating under pressure for about two hours at 248° F., at which temperature not alone the bacteria and their spores are destroyed, but the normal appearance and taste of the milk as well. Part of the sugar is converted to caramel, part of the casein is precipitated, and the milk will no longer form a cohesive coagulum with rennet.

In the opinion of many practitioners, neither pasteurization nor sterilization is free from objection in infant feeding, since even a temperature of 155° F. influences the nutritive value injuriously. Many cases of scorbutus and dyspepsia in infants have been attributed to the use of sterilized milk, and it seems probable that the trouble is connected with the destruction of the zymases normally present. These ferments, the presence of which was announced in 1900 by Escherich, have been studied by Spolverini,[3] who isolated no less than seven, two of which, pepsinic and trypsinic, are present always in both human and cows' milk; the others, amylolytic, lipasic, glycolytic, etc., are not constant. All are soluble, and none can withstand the sterilizing temperature.

To avoid the untoward results of the use of sterilized milk, Freeman[4] proposes that the cream be allowed to rise, and then be removed and subjected alone to sterilization, after which it may be mixed in proper proportion with the skimmed milk, which contains only a very small number of bacteria, since about 99 per cent. of them are carried into the cream layer by the fat globules.

Preservation of milk by the addition of antiseptics is unnecessary, unjustifiable, and possibly injurious. If milk is drawn properly from decently clean animals into clean vessels by clean milkers, and stored in clean places, it will keep sweet quite as long, under ordinary circum-

[1] Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, XXXII. p. 430.
[2] Hygienische Rundschau, July 15, 1901, p. 669.
[3] Archives de Médecine des Enfants, Dec., 1901.
[4] Archives of Pediatrics, August, 1899.

stances and under the usual conditions of frequent delivery, as is desired by the consumer. The addition of antiseptics, which only retard growth of bacteria without destroying them, enables the vendor to supply stale milk instead of fresh, and to dispense with part of the sanitary precautions otherwise necessary. The substances used are by no means wholly innocent in their action on the human system, even in very small quantities and, moreover, it is impossible to control the amount added by a single individual or to be sure that successive handlers have not contributed additional doses. The substances used as milk preservatives are boric acid, borax, salicylic acid, formaldehyde, carbonate of sodium, and chromates.

Boric acid and borax are used generally in combination with each other, experience having shown that the mixture is more efficient than either alone. The minimum efficient quantity of the mixture is about 10 grains to the quart, an amount which even for an adult may well be regarded as a fairly large medicinal dose. In addition to its action on the general system, it exerts a varying effect on the digestion according to the amount present. According to Professor R. H. Chittenden, borax retards the amylolytic action of saliva, boric acid in amounts less than 1 per cent. favors it, and both increase gastric digestion in small amounts and retard it in large.

The use of salicylic acid in milk is not extensive. It is a fairly efficient preservative. Formaldehyde has come into use within a few years. It is a most efficient preservative, and not alone inhibits growth but also kills the bacteria. According to tests made by Dr. C. P. Worcester,[1] 1 part of commercial formalin in 100,000 of milk will postpone the curdling-point 6 hours; 1 in 50,000, 24 hours; 1 in 20,000, 48 hours; 1 in 10,000, 138 hours; 1 in 5,000, 156 hours. Although nothing is known as to the action of small amounts of formaldehyde on the general system, it is not correct to assume that, in the absence of evidence to the contrary, it is necessarily harmless or beneficial. While the occasional ingestion of a small amount of formaldehyde may produce no effect, we cannot reason that its daily use over a long period will be equally non-productive. An occasional drink of water containing lead will do no injury, while its daily use may cause lead paralysis, and in the same way formaldehyde may be the cause of serious disturbances attributed to something else. But whether harmful or not, the use of this agent and of others is unnecessary and unjustifiable. Aside from its possibly poisonous action, there is the objection that it alters the character of the milk proteids; the casein becomes uncoagulable by rennet, except in thick clots, and much less digestible, or wholly indigestible, by the proteolytic ferments. Certain it is that anything that imposes additional burdens on the digestive function of infants and invalids can hardly be regarded as a proper substance for use in food. Annet,[2] after a study of formalde-

[1] Twenty-ninth Annual Report of the State Board of Health of Massachusetts, 1897, p. 559.

[2] The Lancet, Nov. 11, 1899.

hyde and boric acid as milk preservatives, concludes that they are injurious, especially to young infants, and suggests the possibility of a causal relation between their use and the great infant mortality during the hot months.

Carbonate of sodium is a weak agent, and does not postpone decomposition to an extent sufficient to encourage its wide adoption. So far as is known, there can be no objection to its use on the score of injury, except in so far as the assertion that sodium lactate, formed by its decomposition by the free lactic acid, acts as a mild cathartic, is worthy of credence.

The chromates are not extensively employed, but have been found present in preservative powders used in France. Deniges[1] found the normal chromate of potassium in two of these preparations, and the dichromate and chromate together in a third. The latter was recommended in the proportion of 2 grams to 50 liters of milk. According to Froidevaux,[2] such an amount of potassium dichromate is insufficient to retard coagulation and imparts an abnormal intense yellow color to the milk.

The further discussion of the subject of milk preservatives may be looked for below, under the general subject of Food Preservatives.

Adulteration of Milk.—This most important article of food is more subject to adulteration than any other, since it lends itself so readily to fraudulent manipulation. The principal adulterations are the addition of water and the abstraction of cream. The former diminishes the nutritive value, and, if the water used is from an unclean source, increases the possibility of disseminating disease; the latter robs the milk of one of its most valuable constituents. The detection of these adulterations by analysis is not always possible, since a rich milk may be slightly watered or only partially skimmed and still show average quality. Again, even though the watering be fairly extensive, it cannot always be proved that the milk was not of low grade from natural causes, since some cows give milk which on analysis is far below average good milk and bears every resemblance to watered milk. Further, a milk containing very little fat may be naturally poor in that constituent or may be the first part of a milking.

In consequence of the difficulty of proving the addition of water or abstraction of cream, and because of the enormous importance of securing a public supply of at least average good quality, most States have fixed legal standards, to which milk intended for sale must conform. The standard for total solids is commonly 13, 12.5, or 12 per cent.; and for fat, 3, 3.5, 3.7, and 4 per cent. By the adoption of a legal standard, all milk of low grade, whether so by reason of fraudulent practices or be use of poor feed or individual peculiarity of the cow, must be treated alike. By prohibiting the sale of all milk not of a certain grade, it becomes unnecessary to prove fraud or criminal knowl-

[1] Revue International des Falsifications, IX., p. 36.
[2] Journal de Pharmacie et de Chemie, 1896, p. 155.

edge, the allegation of inferior quality being sustained by the results of the analysis.

Other forms of adulteration include the addition of coloring matters for the purpose of concealing watering or skimming, or to give a creamy tint to a very white milk, and the addition of preservatives, and, occasionally, of other foreign substances. The coloring matters commonly used are, annatto, caramel, and combinations of aniline dyes. Their detection is by no means difficult (see Analysis of Milk).

It is a common belief, even among people of more than average intelligence, that milk as found in the market is very largely a mixture of chalk and water. Upon what this absurd tradition is based, it is difficult to surmise, since even though a person were led to practise such a miserable fraud, he would discover that chalk and water will need constant stirring to maintain even the outward semblance of milk, and that a few minutes' standing is sufficient for complete separation into a deposit of chalk and a fairly clear supernatant liquid. A less common, but equally absurd, notion that calves' brains are a common adulterant of milk, arose about half a century ago from the report of a microscopical examination of a milk sediment in which certain particles were detected which bore a resemblance to nerve tissue. Calves' brains do not lend themselves readily to the making of emulsions, the supply is limited, and they find a fairly good market in their true character.

Cane sugar is said to have been found at rare intervals, and gelatin is used occasionally as a thickening for cream. Starch is believed by many to be a common adulterant, but it is used very rarely. In the course of many years' supervision of a large public milk supply, during which several hundred thousand samples of milk were examined for adulterants of all sorts, but one instance of the use of starch fell under the author's notice. This was due to a shortage in the normal supply, which led a dealer to dispense a mixture of water and condensed milk, which latter component had been thickened with starch.

CONDENSED MILK.

Condensed milk is prepared by evaporating milk to about a third or a fourth of its volume in vacuum pans. It is sold in bulk for immediate use, and in hermetically sealed tin cans for use as occasion demands. Most of that sold in tins is made from skimmed milk, and is, therefore, very deficient in fat; and much of it contains a large proportion of cane sugar, which is added to increase its keeping qualities. Condensed milk is in many respects and under certain conditions a valuable food preparation, but its use in infant feeding when other milk is obtainable is not a wise one, since it is deficient in one of the most important elements, and contains another which is not a normal constituent.

KOUMISS AND KEFIR.

These are fermented preparations containing lactic and carbonic acids and a small amount of alcohol. They are produced through the action

of micro-organisms which induce fermentative changes and bring about a partial conversion of the proteids to albumoses and peptones. Both had their origin in Russia, where they have been in use for many years. Koumiss is made generally from the milk of mares, but may be made from that of cows with the assistance of added sugar. Kefir is made more commonly from the milk of cows. Both are effervescent liquids having somewhat the taste of butter-milk, and are valuable in the feeding of the sick and of those with impaired digestive function. The "kefir grains" are small, hard, granular particles which contain the requisite organisms. They are added to the milk after being soaked until soft, and their action is completed in two or three days.

CREAM.

Cream, as already stated, may be defined as milk containing a large excess of fat, and correspondingly lacking in water. The degree of richness is dependent upon the method employed in its separation from the original volume of milk. That obtained by the common method of skimming contains ordinarily about 16 to 24 per cent. of fat, while that separated by the centrifugal machine contains from 20 to upward of 50 per cent., according as the machine is regulated for "light" or "heavy" cream. The latter is so thick as to give rise to a common notion that corn starch is used as an adulterant. This substance, however, is used rarely if ever in this way. Gelatin is employed as an adulterant to a limited extent. A preparation largely advertised to the trade at one time as a "cream thickener" was analyzed by the author, and found to be a mixture of gelatin, borax, and boric acid. The common adulterants of cream are preservatives and coloring agents. The former are used mostly during the hot months; the latter during the winter, when, on account of the difference in feed, the cream has not the characteristic yellow tint so highly prized.

Milk as a Factor in the Spread of Disease.

Milk may act as a carrier of disease or cause of functional disturbance through infectious or poisonous matters originally present, or received or evolved during handling and distribution. Thus, milk may be poisonous by reason of matters derived from the feed or of substances formed after it is drawn; it may contain organisms of various kinds connected with bovine diseases; it may become contaminated in various ways with matter containing the exciting cause of various human diseases.

Poisonous Milk.—Certain plants eaten by cows may cause milk to become unfit for drinking because of toxic properties. Poison ivy (*Rhus toxicodendron*), for example, causes in cows a condition known as "trembles," during the continuance of which their milk is said to cause severe gastric symptoms with great weakness. The most prominent symptoms are pain, nausea, vomiting, constipation, and subnormal temperature. If the milk be boiled, the poisonous properties are de-

stroyed. According to Dr. D. D. Grout,[1] whatever the nature of the poison in milk from cows afflicted with "trembles," it attacks the central nervous system and produces characteristic trembling and profound loss of muscular power. He believes that a peculiar microzyme exists in the blood, and has pathogenic properties, which may be reproduced indefinitely through the milk and through butter and cheese made therefrom.

The leaves of the common artichoke are said[2] to cause abdominal pain, vomiting, and diarrhœa.

As stated on a preceding page, milk may undergo a peculiar form of decomposition resulting in the production of an intensely violent poison, a benzene derivative, known as tyrotoxicon. Fortunately, this is an uncommon change, but it betrays to the consumer no sign of its occurrence at the time of drinking. The effects produced are various, and are well illustrated by the following cases:

CASE I.—Reported by Dr. W. K. Newton and Mr. S. Wallace.[3] On August 7, 1886, 24 guests of one hotel at Long Branch, and 19 of another hotel at the same place, were taken sick soon after supper with the same train of symptoms, which were nausea, vomiting, cramps, and collapse, dryness of the throat, and burning sensation in the œsophagus; in many cases there was absence of diarrhœa, and in several there was active diarrhœa without vomiting. Many had violent vomiting followed by collapse. As a rule, the nausea and vomiting were persistent and obstinate, and accompanied by a tendency to exhaustion and collapse. A week later, 30 guests of still another hotel were seized in precisely the same manner. The onset occurred in from one to four hours after eating, but in one instance the symptoms appeared almost immediately after drinking about a quart of milk. Investigation showed that the trouble was due wholly to milk, for only the milk-drinkers were seized, and those who had had no other food were the worst sufferers. The three hotels were served by one dealer, who made two deliveries daily. The milk of the second delivery was the cause of the mischief in each outbreak. It was drawn at noon, and, without being cooled at all, was carted eight miles in the heat of the day. The cows were healthy and well fed. In a portion of the milk that caused the third group of cases, the presence of tyrotoxicon was demonstrated.

CASE II.—This was a most extraordinary outbreak, limited to a family consisting of father, mother, son, and daughter, of whom all but the first mentioned died. The family physician called Professor V. C. Vaughan in consultation after the fourth member of the family was seized, and from his report of the case the following facts are taken. The first one seized was the father, a man of fifty years. When first seen, he was vomiting severely, his face was flushed, and his temperature was subnormal (96° F.). There was marked throbbing of the

[1] Quoted in American Medicine, Aug. 31, 1901.
[2] Milchzeitung, 1891, p. 40.
[3] Medical News, September 25, 1886, p. 343.

abdominal aorta, the tongue was heavily coated, and the breathing was very labored. The pupils were dilated, and much of the body was covered with a rash. The vomiting continued some hours, the vomitus being colored with bile. The bowels had not moved, but under the influence of a cathartic, a stool occurred on the following day. Retching and vomiting continued during that day and night, and there was persistent stupor. During the following three days, there was but little change. Then improvement began, but recovery required a month. The son, a strong youth of eighteen, was the next to be seized, four days after the beginning of his father's sickness. The symptoms were similar, but were more violent, and there was no rash. On the following evening, the mother, about forty-five, was seized in the same way, and on the succeeding evening, the daughter also. On the day following the last seizure, none of the cases showed improvement. The temperatures were subnormal, 94° and 95° F. All complained of a burning constriction in the throat and difficult swallowing, and called frequently for ice. Two days later, the mother and son died; the daughter grew worse, became unconscious, remained so three days, and then died.

Post-mortem examination in the case of the daughter revealed no characteristic lesions to account for death. The outbreak was most carefully and thoroughly investigated from every standpoint, and the conclusion reached was that tyrotoxicon was the cause. The milk had been kept in a buttery which was in a most unsanitary condition. During three years, the family had suffered frequent attacks of like character, but they were much less severe. Fresh milk, placed in the buttery over night, and then examined for tyrotoxicon, gave unmistakable chemical and physiological evidence of that poison. Fresh milk inoculated with dirt from the buttery floor also developed it, as did also other portions treated with vomitus, stomach contents, and aqueous extract of the intestines, while a fifth specimen untreated remained free from it. All the evidence in this case pointed to the more or less constant presence of poison in the milk, and the wide variation in the time of seizure in the final outbreak indicates that all were not affected by the same day's supply.

Milk from Diseased Cows.—The milk of cows suffering from the prominent cattle plagues is more or less altered in composition, and there appears to be evidence that it may be actually dangerous.

In *rinderpest*, the proteids are much increased—in fact, more than doubled; the mineral constituents are considerably increased, and the fat and sugar are diminished.

In *foot and mouth disease*, the total solids are increased considerably, or diminished at different stages, and the milk will sometimes coagulate on boiling, by reason of the excessive amount of coagulable proteids. There is reason to believe that this disease may be communicated to other animals through the milk, and there is evidence that the use of the milk by man will produce local lesions in the mouth and throat. Thus, Notter and Firth[1] mention an epidemic of sore throat at Dover,

[1] The Theory and Practice of Hygiene: London, 1896, p. 305.

in 1884, in which there were 205 cases of vesicular eruption in the throat or on the lips, enlarged tonsils, and in most cases enlarged glands of the neck, all occurring within a week in persons supplied by a single dairy where the disease existed. It is asserted by Pott[1] that such milk in the raw state may induce a similar affection in man, and especially in children.

In *anthrax*, the milk has an abnormal appearance and decomposes rapidly. The specific organism has been isolated in active condition by Boschetti[2] from milk as late as fourteen days after it had been drawn.

In *actinomycosis*, particularly if the udder is involved, the milk should be avoided, although there appears to be little direct evidence bearing upon transmission of the disease to man by this means. It is certain, however, that the disease does occur sometimes in man, and though in the matter of transmission of disease from animals to man nothing should be taken for granted, it is commendable in such cases of lack of positive knowledge to err on the side of safety, and to avoid and prohibit the use of such milk.

The milk of cows afflicted with *garget*, an inflammatory condition of the milk ducts, is believed to have caused epidemics of gastro-intestinal irritation, and there is reason to believe that it may be a common cause of cholera infantum. In an investigation instituted to determine the cause of diarrhœa among the consumers of milk of a certain dairy, Lameris and Van Harrevelt[3] discovered the presence of streptococci in great numbers in the udder of a cow which recently had recovered from an attack of garget. Whether in this particular instance these micro-organisms were the cause of the disturbance among the consumers, cannot definitely be asserted, but according to the researches of Escherich, Adametz, and others, the severe diarrhœas of infancy are due largely to the presence of *Streptococcus pyogenes*. This and other pathogenic organisms appear to be exceedingly common in ordinary market milk, and in the milk of cows with no apparent local disease. Thus, Eastes[4] discovered streptococci in 106 of 186 samples examined; Beck,[5] in 35 of 56 samples of the Berlin supply; Bergey,[6] in 20 of 40 samples of market milk, and in 3 of 59 samples from first-class dairies. Reed and Ward[7] have recorded the case of a cow, one of the Cornell University herd, apparently healthy, whose milk yielded streptococci at intervals extending over two years and a half. When the animal was killed, the udder was examined, and showed an abundance of the organisms. From the secretions of certain diseased udders, Klein[8] isolated two varieties of pyogenic bacteria—*B. diphtheroides* and *Streptococcus radiatus* (*pyogenes*).

Other pathogenic organisms commonly present in milk include mi-

[1] Münchener medicinische Wochenschrift, July 25, 1899.
[2] Giornale di Medicina Veterinaria, 1891.
[3] Zeitschrift für Fleisch- und Milchhygiene, 1900, p. 114.
[4] British Medical Journal, Nov. 11, 1899.
[5] Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, 1900, p. 430.
[6] American Medicine, April 20, 1901, p. 122.
[7] Centralblatt für Bakteriologie, 1901, XXIX., p. 496.
[8] Journal of Hygiene, January, 1901, p. 78.

crococci, found by Bergey in 36 of 40 samples of market milk, and in 16 of 59 samples from first-class dairies; *Staphylococcus pyogenes aureus*, found by the same investigator in 3 of 8 samples from individual cows of first-class dairies; by Leblanc,[1] in the ducts of 10 of the 24 teats of 6 dairy cows examined; and *Staphylococcus aureus* and *albus*, found by Leblanc, v. Hellens, and others. *B. coli communis* is present almost invariably in milk from all sources, and *Proteus vulgaris* is found frequently.

The presence of the various pyogenic bacteria in milk, whether due to their existence within the milk ducts or to even slight lesions on the hands of the milkers, is a matter of grave concern as a common cause of serious gastro-intestinal disorders, especially in children in their first years.

It would appear from a report made by Gaffky,[2] that the milk of cows suffering from specific enteritis may be a cause of sickness. Three persons connected with the Institute of Hygiene at Giessen were seized, after drinking milk from a cow suffering from such a disease, with nausea, vomiting, diarrhœa, and mental confusion. One recovered in a few days, the others in about four weeks. The milk was drunk in the raw state.

Concerning the agency of milk of tuberculous cows in spreading *tuberculosis*, there is, as in the case of tuberculous meat, a wide divergence of opinion. There can be no doubt that the milk of such cows may convey the infection to other animals, but whether to man cannot be definitely stated, because of the impossibility of experimentation, and since, in any case of supposed transmission, very many other possible agencies must be eliminated. As stated on a preceding page, local infection by meat through wounds incurred at autopsies of tuberculous animals is not impossible, but cases of similar infection through milk are exceedingly rare. Salmon[3] cites but 3 cases in all; one, from the application of cream to a leg supposedly poisoned by ivy; a second, from milking with a wound in one finger; and a third, from attempted removal of tattoo-marks by the introduction of milk through needle-punctures.

There can be no doubt that the tubercle bacillus finds its way into milk, particularly if the udder is involved, but even when not. This was asserted so long ago as 1889 by Professor H. C. Ernst,[4] who, after a very extended inquiry, proved that the milk of cows with tuberculosis in any part of the body, and with no local lesion of the udder whatever, may contain the bacillus. This finding has been confirmed by a number of more recent observations. Especially noteworthy is the investigation pursued by Drs. Rabinowitsch and Kempner,[5] who obtained positive results from inoculation experiments on guinea-pigs with the milk of 10 out of 15 cows that had reacted to tuberculin. Of these

[1] Lyon médical, 1900, p. 561.
[2] Deutsche medicinische Wochenschrift, 1892, No. 14.
[3] Bulletin 33, Bureau of Animal Industry, 1901.
[4] American Journal of Medical Sciences, November, 1889.
[5] Zeitschrift für Hygeine und Infectionskrankheiten, XXXI., p. 137.

10 animals, only 1 showed clinical evidence of involvement of the udder, and only 1 other showed any sign of it on microscopical examination. Others who have obtained positive results from animals with normal udders include Bollinger, Delépine, Bang, and Adami.

Similarly, the milk of a tuberculous mother may be infective, even though no mammary lesions exist. Such an instance is reported by Roger and Garnier:[1] The woman died, seventeen days after confinement, with pulmonary tuberculosis. On the fourth day after delivery, 2 guinea-pigs were inoculated with her milk, one of them with positive results. The child lost weight from birth, and died at six months with tubercular lesions of the mesenteric glands, liver, kidneys, and spleen.

But the question of excretion of bacteria by active mammary glands with no apparent lesions has not been studied exhaustively. According to Basenau,[2] only those bacteria which are capable of acting on the walls of the blood-vessels so as to cause hemorrhages are able to pass from the blood into the milk, and in those cases in which *B. tuberculosis* has been detected in the absence of evidence of mammary lesions, the chances are that more or less alteration of the vessel walls has occurred in consequence of disturbed nutrition. The experiments of Basch and Weleminsky[3] lead one to the conclusion that Basenau's position is correct. They infected animals with different species of pathogenic organisms, and found that, even when the blood teemed with anthrax bacilli, the milk showed no evidence of their presence unless there were local conditions especially favorable, such as vascular lesions, which may be caused by the hemorrhage-producing bacteria. It has been demonstrated by Ostertag[4] that the milk of cows which show no evidence of tuberculosis beyond reacting to tuberculin contains no bacilli, and that calves and pigs fed thereon for months do not become tuberculous.

It is asserted commonly that the use of milk from tuberculous cows is a positive danger to public health, and attention is directed to the persistently high rate of mortality from tuberculosis in all its forms among very young children, and to improvement in the death-rates from other causes. It is asserted that this condition can be explained in only one way; that is, that a very large proportion of market milk is derived from tuberculous cows, and thus bottle-fed children, if at all susceptible, become infected.

As to the probable proportion of infected market milk, owing to the wide differences in results obtained by various investigators, no definite statement can be given. Rabinowitsch, for example, found it to be 28 per cent.; Massone[5] by inoculation experiments placed it at 9; Ott[6] at 11.6. Sladen[7] found that more than half of the samples taken from

[1] Comptes rendusde la Société de Biologie, March 2, 1900.
[2] Archiv für Hygiene, XXIII. (1895), p. 44.
[3] Ibidem, XXXV. (1899), p. 205.
[4] Zeitschrift für Hygiene und Infectionskrankheiten, XXXVIII. (1901), p. 415.
[5] Annali d'Igiene Sperimentale, 1897, p. 939.
[6] Zeitschrift für Milch- und Fleischhygiene, 1898, No. 8.
[7] The Lancet, January 14, 1899.

the supply of the colleges at Cambridge (England) conveyed tuberculosis to guinea-pigs on inoculation; but Eastes[1] found the bacillus in but 11 out of 186 samples of milk which he examined. Others have obtained results anywhere within the range of 6 to 50 per cent. Doubtless the differences are due to variations in local conditions, to differences in technic, and to accidents always attending hap-hazard securing of any article of food in open market.

Taking the mean of the figures given, and accepting that as a fair approximation of the extent to which public supplies are infected, it must be agreed that, if infection through milk is possible, the amount of disease so caused is quite small in proportion to the number of the population who are exposed daily to the danger. There are but few reported cases in which the influence of other possible conditions can be excluded so thoroughly as to leave no reasonable doubt of the causal relation of milk. Single instances are necessarily of less value than groups of cases, and the latter are much less common than generally is supposed. From the number available the following are selected as illustrations:

Brouardel[2] records the death of 7 children with no hereditary taint, inmates of a convent, from tuberculosis supposedly induced by the use of milk from a cow with tuberculosis of the udder. Another case reported by him, and quoted by Freudenreich,[3] is one in which 5 of 14 girls in a boarding-school became infected and died. The milk which they had used daily came from a tuberculous cow.

Demme[4] reported as the only instance in his experience in which all other causes could satisfactorily be excluded, a group of 4 infants of healthy parentage fed upon uncooked milk of tuberculous cows. They all died of tuberculosis of the intestine, and the diagnosis was confirmed by autopsy. Later, he reported[5] still another death from the same cause at four months. In this case also there was absolutely no family history of tuberculosis. After the confirmation of the diagnosis by autopsy, the cow was slaughtered and found to be tuberculous.

A more extensive outbreak among older children was reported by Ollivier to the Academy of Medicine, Paris, on February 24, 1891. A woman of twenty-one years, of good family history, who had always enjoyed good health, died of tubercular meningitis shortly after taking up her residence in a boarding-house in which within a short time previously 11 school girls had been seized with tuberculosis. It was learned that the milk supply was derived from a single animal which was extensively tuberculous. Shortly afterward, still another girl died of phthisis pulmonalis in the same house.

Some of these cases, if not all, may be accepted as very strong evidence that tuberculosis may be spread through the agency of milk.

[1] British Medical Journal, November 11, 1899.
[2] Annales d'Hygiène publique, XXIV., p. 65.
[3] Les Microbes et leur des Role dans la Laiterie, Paris, 1894, p. 45.
[4] Jahresbericht über die Thätigkeit des Jenner'schen Kinderspitals in Bern, 1882, p. 48.
[5] Ibidem, 1886, p. 20.

But if it is true that so large a proportion of the milk supply is from diseased cows, and that the disease is communicable in this way, it follows that with the vast majority of drinkers of raw milk the bacilli perish or are discharged without gaining entrance to the tissues.

Granting that much of the public milk supply is derived from tuberculous cows, and that it is consumed very largely in unsterilized condition by very young children, one would naturally expect, if the bovine bacillus is markedly infective to man, to find a very high death-rate from abdominal tuberculosis among the very young. It is asserted that this is the case, and elaborate arguments in favor of the statement that tuberculous milk is responsible for a great part of the constantly high infantile death-rate have been based on figures given by the late Sir R. Thorne-Thorne, in his Harben lectures, in November, 1898, showing that, whereas in England and Wales the returns for 1891–1895, compared with those for 1851–1860, indicate a reduction in mortality from phthisis at all ages of 45.4 per cent., and from all forms of tuberculosis of 39.1 per cent., the decrease in tabes mesenterica was for all ages only 8.5, and for children under five only 3 per cent.; and that, moreover, for children under one year there was not only no reduction, but an actual increase of 27.7 per cent. Such figures, emanating from so high an authority, would seem to admit of but one explanation, namely, that infected milk is a danger hardly to be overrated. But these figures are directly opposed to clinical experience elsewhere and, as will appear, are incorrect. Dr. D. Bovaird[1] points out that it is only in England that reports indicate any considerable number of cases of primary intestinal tuberculosis, and asserts that it is very rare in and about New York City, and that the evidence connecting tuberculosis in children with infected milk is very meagre. Koch has called attention to the great infrequency of primary tuberculosis of the intestine among children in institutions in Berlin; and Biedert,[2] too, asserts that the amount of tubercular infection through the alimentary canal is very small. Adami[3] is of the opinion that tuberculosis of young children, and especially peritoneal and intestinal tuberculosis, is remarkably rare in the great cities of North America; but Jacobi,[4] while admitting that primary tubercular ulcerations of the intestine and primary tuberculosis of the mesenteric glands are rare, holds that peritoneal tuberculosis is very common. Adami cites the mortality returns for Montreal for the year ended June, 1900, showing that of 935 deaths from tuberculosis, but 4 were of children under fourteen, and 3 of these were from abdominal tuberculosis in children under five years. Crookshank[5] dissents from the opinion that abdominal tuberculosis of children is connected with infected milk, but believes that not sufficient consideration is given to the possibility of infection from human sources.

The fallacy of Thorne-Thorne's figures has been pointed out by Carr,

[1] Archives of Pædiatrics, Dec., 1901.
[2] Berliner klinische Wochenschrift, November 25, 1901.
[3] Philadelphia Medical Journal, February 22, 1902.
[4] New York Medical Journal, January 25, 1902.
[5] The Lancet, November 2, 1901.

Guthrie, Donkin, and others, and all arguments based thereon must fall to the ground. In December, 1898, Carr[1] showed that the vast majority of cases returned as tabes mesenterica were probably of marasmus, due to gastro-intestinal catarrh. Guthrie[2] concluded from the results of 77 autopsies performed by him on tuberculous children that the disease begins far more commonly in the chest than in the abdomen, and that tabes mesenterica as a cause of death in young children is practically unknown or extremely rare. Donkin, who contends that the original significance of the term "tabes mesenterica" no longer holds, says:[3] "We all know that all kinds of intestinal and other disorders are constantly styled 'tabes mesenterica' by those who fail to cure them."

Notwithstanding the paucity of cases which offer strong evidence of a causal relation between infected milk and the occurrence of tuberculosis, and in spite of the now recognized differences between the bovine and human bacilli, the possibility of danger in individual cases cannot lightly be brushed aside. According to Theobald Smith,[4] it is quite possible that something interferes with the absorption of bovine bacilli, while allowing the human bacilli to pass; and while racial differences probably prevent the absorption of bovine bacilli under ordinary circumstances, and a few bacilli are harmless, there is danger if the digestive tract is flooded with bacilli from tuberculous udders. Ostertag[5] advocates the culling out of all cows showing clinical evidence of tuberculosis (beyond reacting), and especially of all with lesions within the udder.

Leblanc[6] is of the opinion that the milk of tuberculous cows is dangerous, not on account of the bacilli, but on account of the toxins that it contains, for it has been proved to have toxic properties. Michellazzi has shown that such milk injected into tuberculous animals causes a reaction, and that the milk of a tuberculous mother will in time prove toxic to her child.

Milk Contaminated from without with Organisms Related to Human Diseases.—Milk may become contaminated with infective matter in various ways. It may receive it from the hands, person, and clothing of the milkers and others by whom it is handled, whether they are themselves sick or convalescent, or acting in the capacity of nurse or attendant for others; it may acquire it from unclean vessels rinsed in polluted water, or from water with which it has fraudulently been mixed. Outbreaks traced to milk generally involve a considerable number of persons, and appear with some suddenness. In fact, it is the simultaneous appearance of a large number of cases that draws attention to the water supply or milk as a common cause. Sporadic cases are rarely traceable to milk.

On account of the danger of specific contamination of milk, no per-

[1] The Lancet, 1898, II., p. 1662.
[2] Ibidem, 1899, I., p. 286.
[3] British Medical Journal, October 14, 1899, p. 1046.
[4] Medical News, February 22, 1902.
[5] Loco citato.
[6] Lyon médical, April 14, 1901, p. 561.

son sick with or convalescent from infectious disease, and no person having to do with the care of the sick, or with the disposal of their excreta, or with the washing of their linen, should be allowed to handle milk intended for the use of others. Public authorities are rapidly becoming awakened to the importance of restrictive measures in this regard, and in many communities it has been made a criminal offence to fail to give notice of the presence of cases of infectious disease at the place of production of milk or among those engaged in its distribution and sale.

Diphtheria.—A large number of epidemics have been reported in which a positive connection with the milk supply appears to have been fairly well made out; but so far as is known, there is no connection between any disease of the cow and that which we know as diphtheria, although a number of outbreaks of diphtheria have been reported as traced to garget. The specific organism of diphtheria may be introduced into milk from the discharges of persons employed in the handling and distribution of milk before they have recovered thoroughly from the disease. Dr. J. W. H. Eyre[1] found the bacillus of diphtheria in samples of milk supplied to a large school where a number of cases of the disease had occurred. The organisms gave the usual characteristics, and no reason appears for doubting their identity.

Schottelius[2] proved that the bacillus of diphtheria can grow very rapidly in raw milk, less so in sterilized milk at ordinary temperature, but very much better at 37° C. Inasmuch as the organism may persist for long periods after the disease apparently has disappeared, and may be present in the throats of persons in apparent health, it need not excite wonder when it is reported present in milk.

Cholera.—Undisputed evidence of the connection between milk and Asiatic cholera is not very common. There is some disagreement as to the viability of the cholera organisms in milk; thus, Hesse[3] found that fresh, raw milk exerts a destructive influence on them; that, in fact, they begin to die as soon as they are mixed with it. He found that they die at ordinary room temperature within 12 hours, and at incubator temperature in from 6 to 8 hours. The age of cultures, the nature of the culture media, and the addition of the latter to the milk with the bacteria, appear not to affect the result. Sterilized milk was found to be a better culture medium. Basenau[4] disagrees with Hesse. He found that uncooked milk does not kill the organisms in 10 hours, that they are active after 38 hours, and that up to the point of coagulation of the milk they increase considerably in number. He found that in polluted milk they remain active at least 32 hours at different temperatures (room temperature, 24° and 37° C.), and that they remain active even after the milk has coagulated.

Weigmann and Zirn[5] found that the length of time cholera bacteria

[1] British Medical Journal, September 2, 1889.
[2] Centralblatt für Bakteriologie, Abth. I., XX., No. 25.
[3] Zeitschrift für Hygiene und Infectionskrankheiten, XVII., p. 238.
[4] Archiv für Hygiene, XXIII., p. 170.
[5] Centralblatt für Bakteriologie, etc., 1894, No. 8.

remain active depends upon the ratio they bear to the number of other organisms present, and that in order to survive for many hours they would have to be added to milk in exceedingly large numbers.

The evidence that cholera can be disseminated through the agency of milk is exceedingly limited, and about the only case free from doubt is that recorded by Simpson,[1] who relates that 9 cases of cholera occurred suddenly on a ship in the harbor of Calcutta, 10 men of whose crew had obtained milk from a native. One drank but little and escaped, 4 died of undoubted cholera, and 5 were very sick with diarrhœa. Eight others who used condensed milk only, and those who used no milk whatever, were unaffected. It was learned that the vendor had diluted the milk about one-fourth with water from a tank to which dejections from cholera patients had gained access and in which the clothes of the patients were washed.

Scarlet Fever.—In December, 1885, occurred what has become commonly known as the Hendon outbreak of scarlet fever, due to a disease of cows, and since that time a number of other epidemics have been traced apparently to a common milk supply. In the Hendon case, a number of cows were or had been sick with an infectious eruption of the udders, and there can be no doubt that the disease under consideration was spread through the agency of milk coming from this dairy; but other cows having the same disease caused no trouble, and the possibility of contamination from human sources could not be excluded absolutely. A number of other outbreaks of the disease have somewhat doubtfully been ascribed to similar teat eruptions, but in no case is the evidence conclusive. On the other hand, there is undoubted evidence that the disease has many times been spread by milk from farms where children and others were sick with it.

In tracing epidemics of this and other diseases to a common cause, there is always danger of lending too much importance to coincidence, and of coming thereby to unwarranted conclusions. As an illustration, the following case may be cited: In 1897, in one of the outlying wards of Boston, a large number of cases of scarlet fever occurred with some suddenness among children chiefly of the well-to-do class. Naturally there was much disturbance of the public mind, and an investigation was undertaken immediately. It was ascertained that nearly all of the families concerned were supplied by one milkman, who "raised" all the milk which he handled, and the responsibility for the outbreak was at once laid at his door. His premises were examined by the health authorities and found to be in excellent condition. No case of disease or indisposition had occurred in his family or among his help within a number of months, nor had he or anybody on the place, so far as could be ascertained, been in contact with any case of scarlet fever or of any other infectious disease. His cows were examined by a thoroughly competent veterinarian and pronounced in every respect healthy. Nevertheless, public excitement ran so high that his business fell away very considerably. Had a single cow shown the slightest

[1] Indian Medical Gazette, May, 1887.

evidence of an eruptive disease of the teats, the epidemic might have been hailed as another Hendon outbreak, and been quoted in sanitary history as a noteworthy example. The fact that the great majority of cases occurred among his patrons was easily explainable, for he was known to be a careful, cleanly, honest dealer, and was, therefore, the very sort of man to attract the particular class whose homes were invaded. The children affected belonged to closely affiliated groups of playmates. Further investigation revealed the fact that the first case was of a lad whose family was not a customer of the suspected dealer, and that, immediately before taking to his bed, he had been playing with a number of those who were among the next to be seized. These in their turn had been associated with others, and so the infection had spread. Thus, what might have served as a most useful example of a milk-borne epidemic of scarlet fever fell to the ground, and the unfortunate dealer was absolved from responsibility.

Typhoid Fever.—There can be no doubt that, in the spread of typhoid fever, milk plays a part only second in importance to that of drinking-water. A very great number of epidemics have been traced beyond a possibility of dispute to milk coming from farms where cases of the disease have occurred. The contamination is brought about by the hands of the milkers or other handlers, who, in addition, assist in nursing, or by the addition of infected water, or through washing pails, cans, and other vessels in such water.

From time to time, tabulated analyses of outbreaks supposed to be due to contaminated milk have been published, but a very large proportion of the cases included are based on very insufficient evidence, sometimes exceedingly slight, such as that a cow had drunk from water into which drainage from the barnyard had had access. But within recent years, a number of extensive epidemics in this country and elsewhere have been traced with as much definiteness to the milk supply, as have others to the water supply, and with the same and only defect that the bacteriological proof has been lacking. As is the case when outbreaks occur from polluted water, when attention is drawn to the possible cause, the bacteriological evidence is no longer obtainable, the conditions having changed during the period of incubation.

The State Board of Health of Massachusetts has traced a number of extensive epidemics to the use of polluted milk, but in no instance has the organism been found in the milk. In the city of Boston also, where the local authorities keep a constant eye on the reports of typhoid fever cases with particular reference to the possibility of dissemination through milk, a number of small outbreaks have been traced definitely to milk supplies derived from small farms where persons sick with the disease were nursed by those who had milked the cows and handled the milk, and in these instances also the bacteriological evidence is lacking.

That the organism can retain its vitality in milk, and even in sour milk, has definitely been settled. Hein found the organism in sour milk at 13°–18° C. after thirty-five days, but not after forty-eight. Hesse has found it in sterilized milk after four months. Drs. Fraenkel

and Kister,[1] having reason to believe that the unusual amount of typhoid fever at Hamburg during the summer of 1897 was due in part to infected buttermilk, undertook the study of the question whether *B. typhosus* can exist in that fluid, concerning which point there had been more or less of conflicting testimony. Obtaining some samples, they first investigated the number and identity of the contained bacteria, and learned that, while the number varied widely, the species were always about the same. Finding no pathogenic organisms, they sterilized specimens in test-tubes a half hour a day for three days, then planted the typhoid bacillus in them and kept them at different temperatures; on ice and at 22° and 37° C. Loops were taken from each from time to time and planted, and each yielded positive results. The specimen kept at room temperature was under observation nine days; the others were not examined after the third. The specimens of fresh buttermilk containing all its bacteria were planted and kept under the same conditions, and from them the same results were obtained. Yet there was this difference, that there was always a diminution in the number of the pathogenic organisms, and this was the more marked, and sometimes very rapid, with increasing temperatures.

Cholera Infantum.—In every large community, it has become customary to expect as a normal condition a large death-rate among children with the advent of hot weather. This increased death-rate is limited very largely to the very early age periods and to children fed on cows' milk, and while children of the poor are the ones most commonly attacked, those of the well-to-do are by no means free. During the siege of Paris, the infant mortality was reduced to a half of its yearly average, although the general death-rate had doubled. This unusual condition was attributed, no doubt correctly, to the fact that mothers were obliged to nurse their infants when they could, on account of the great scarcity of cows' milk and other foods.

The common milk bacteria are ordinarily harmless, but it appears that some species under certain conditions produce toxins in sufficient amounts to cause gastric and intestinal disturbances. According to Baginsky,[2] a large part of the annual amount of cholera infantum is due to these products (see under *Garget*, p. 99).

Dr. E. W. Hope[3] investigated over a thousand cases of autumnal diarrhœa, and found that, of 233 deaths of infants under three months, only 16 had not received other than their natural food. That is to say, the deaths among artificially fed children under three months of age were fifteen times as numerous as among those nursed. In no less than 22 per cent. of the whole number of fatal cases, other members of the household had suffered from diarrhœa. The most striking instance of the communicability of the disturbance was that at an infants' home in which were 10 children under the age of five months, all in perfect health. An infant of two months was admitted in July with vomiting

[1] Münchener medicinische Wochenschrift, February 18, 1898.
[2] Berliner klinische Wochenschrift, 1894, Nos. 43 and 44.
[3] Public Health, July, 1899.

and diarrhœa, and within a few days 6 of the other infants and the nurses were sick in the same way. The 4 other children were taken away at once. The admitted child and the 6 that became infected all died. The 4 that were taken away were saved.

Bacteriological examination of milk has shown the presence of extremely active organisms, including *B. enteritidis sporogenes* of Klein,[1] which has been found by its discoverer in the ileum contents of children and adults with diarrhœal conditions, but not in a condition of health. It has been found by Andrewes in the discharges of cases of sporadic diarrhœa of adults, and by Klein in three different outbreaks among the inmates of a single hospital. It is a common saprophyte found in sewage, in polluted rivers, and in manured garden soil, and is very commonly detected in milk, the use of which has not been followed by untoward results. Under certain unknown conditions, it becomes highly pathogenic, and recent milk cultures are intensely virulent when inoculated subcutaneously in guinea-pigs.

It is probable that to this organism was due an outbreak of milk-poisoning in Malta, described and investigated by J. Zammit.[2] In one village, 5 families comprising 12 persons were seized with vomiting, diarrhœa, and cramps, and 2 children succumbed. Post-mortem examination revealed nothing except congestion of some of the viscera. Subsequently, in another village, 17 persons in 5 houses were attacked with severe gastro-enteritis and collapse. The symptoms, which came on in all cases about three hours after drinking milk, included vomiting, diarrhœa, acute pain in the stomach and bowels, cramps in the extremities, weak and irregular pulse, and cold and clammy skin. The persons concerned in both outbreaks obtained their milk from the same dealer, whose cans, which had a sour smell, yielded on bacteriological examination a bacillus having all the characteristics of the one mentioned. Families which were supplied by the same dealer, but directly from the goats, showed no symptoms, and the goats themselves were free from disease.

Andrewes[3] has described 3 much more extensive outbreaks, referred to above, due to the same organism, in one of which the offending food was found to be rice pudding made with milk. The first and second outbreaks, in which no one article of food could be incriminated, involved respectively 59 and 146 patients; the third involved 86. In all 3 outbreaks, the great majority of the attacks were mild, but in some of the more severe cases, the discharges contained mucus and blood. In all 3, the organism was found in the stools, and in the second, it was found in the milk given out on the previous day. In the third, it was impossible to obtain any of the milk, but the pudding made with it yielded the organisms, in spite of the heat to which the compound had been subjected during its preparation. It was found by direct experi-

[1] Centralblatt für Bacteriologie, etc., XXII., Abth. I., Nos. 20 and 21; XXIII., Abth. I., No. 13.

[2] British Medical Journal, May 12, 1900, p. 1151.

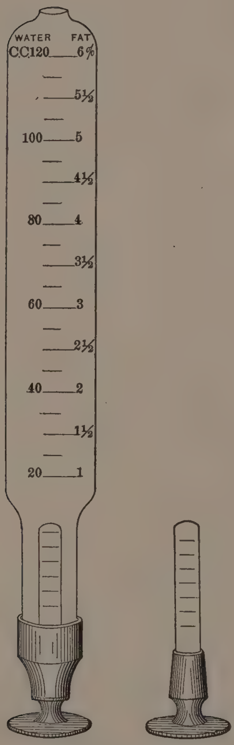
[3] The Lancet, January 7, 1899.

ment that the interior of such a pudding did not attain a temperature above 98° C. during cooking, a temperature below that necessary for the destruction of the spores, which are among the most resistant known.

Analysis of Milk.

For ordinary purposes of determining the quality of milk, the presence or absence of added water, and whether it has been robbed of its cream, a complete chemical analysis is by no means always necessary, since much may be learned from simple inspection by means of the lactodensimeter and the lactoscope. The lactodensimeter (Fig. 2), or lactometer, is merely a large hydrometer with a stem graduated to show specific gravities ranging from 1.015 to 1.040. The lactoscope, invented by Professor Feser, is an instrument designed to indicate the approximate fat content of milk. It consists of a glass cylinder, into the base of which a smaller cylinder of white glass, closed at the top and mounted on a metallic base, is fitted. The larger cylinder is graduated along the side; the smaller one bears a number of black horizontal lines. The instrument is shown in Fig. 1.

FIG. 1.



Feser's lactoscope.

FIG. 2.

Lactodensimeter.

The principle of the instrument is based upon the fact that the opacity of milk is due mainly to the fat globules in suspension, and that, therefore, the richer a milk is in fat, the greater is its opacity, and the more it must be diluted to reduce the opacity to such an extent as to permit the passage of light.

The method of use is as follows: Four cc. of the specimen are delivered from a pipette into the cylinder through the opening in its upper end, and then water is added in small portions and thoroughly mixed by inversion of the instrument, the orifice being kept closed by the tip of the forefinger. As soon as the successive additions of water have reduced the opacity of the mixture to such an extent that the black lines on the white cylinder can be discerned so distinctly that they may be counted, the height of the liquid on the scale is noted and the per-

centage of fat indicated is read. Four cc. of skimmed milk will require so little water that, when the lines can be seen, the level of the mixture will be very low on the scale, while with rich milk it will be correspondingly high, and with cream the whole cylinder will be filled, and even then the lines cannot be made out.

Control analyses show that the instrument gives very fairly accurate results. Neither of these instruments alone can be depended upon to indicate the true quality of milk, excepting in the case of samples which are either very good or very bad. The specific gravity alone is especially fallacious as a guide for the following reasons: The specific gravity of normal milk at 59° F. ranges between 1.029 and 1.034. The removal of cream causes it to rise; the addition of water causes it to fall. A normal milk when robbed of its cream may show a specific gravity of 1.036, and then if a small amount of water is added, the gravity is brought down to 1.032; that is to say, within normal limits. Thus, a milk after being doubly treated so as to reduce its nutritive value, may show a normal specific gravity, and, on this test alone, be classed as pure. Nor is this the only objection to a system of inspection of this most important food based upon the use of the lactometer, since milks exceptionally rich in fat have a specific gravity below the normal, and thus may be condemned as watered.

The lactoscope alone is also not to be depended upon in all cases, since a milk which shows a normal content of fat may be one of considerable richness in that constituent and extensively watered. Thus, a specimen containing originally 4.50 per cent. of fat may be watered very considerably, and yet show 3.75 per cent. by the lactoscope.

By combining the use of both instruments, however, the fallacies of either are exposed. A normal specific gravity shown by the one and a normal fat content revealed by the other will indicate that, even if the milk has been tampered with, it yet possesses average richness. A normal specific gravity with a low percentage of fat will indicate skimming and watering; low specific gravity with normal or low fat, watering; and high specific gravity with low fat, skimming. Low specific gravity with very high fat will indicate unusual richness; thus, cream has a very low specific gravity, due to its preponderance of fat. As a test of the accuracy of this process of examination, the author[1] caused to be analyzed under his supervision 1,714 specimens which appeared by those tests to be of good quality, and of this number but 8 were found to have deviated materially from the statute requirement of 13 per cent. of total solids.

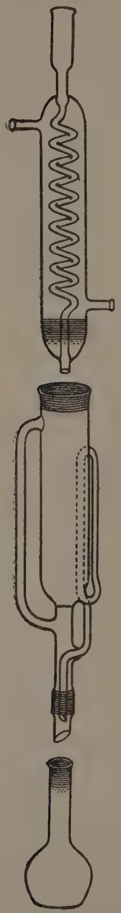
Determination of Specific Gravity.—In taking the specific gravity by means of the lactodensimeter, the milk is mixed thoroughly, in order to insure homogeneity, by pouring from one vessel into another; a cylinder of sufficient depth to allow the instrument to float freely is filled with the milk, and the instrument is carefully inserted, not dropped, down to the bottom, and then released. When it comes to rest, the reading of the stem at the level of the surface of the liquid is

[1] Thirty-first Annual Report of the Inspector of Milk, Boston, 1889, p. 11.

noted. It should be borne in mind that air bubbles are retained rather tenaciously by the milk, and tend to lower the density, and, therefore, in mixing the milk, too violent action must be avoided, and a short time should be allowed for the bubbles present to rise to the surface and escape.

Inasmuch as the gravity varies with the temperature, and the instrument is graduated for 59° F., either the milk should be brought to that temperature, or a correction should be made according to the deviation above or below that point. If the milk is colder, the reading will be too high, and, if warmer, too low. It is more convenient to make a correction for temperature than to heat or cool the specimen to the normal point. The deduction of a half degree of gravity for each five degrees of temperature below 59°, or the addition of the same amount for each four degrees above 59°, will be found to be approximately accurate corrections.

FIG. 3.



Soxhlet extraction apparatus.

Determination of Fat.—For the accurate determination of fat, several methods are in use, including the following:

I. **The Paper-coil Extraction Method.**—This process requires strips of thick filter-paper, free from substances soluble in ether and alcohol, about 6.25 by 62.5 cm., and a Soxhlet extraction apparatus. The most approved form of the latter consists of three separate pieces which fit together by ground-glass joints (see Fig. 3). The top and bottom pieces are, respectively, an upright Liebig condenser and a flask. The middle piece, which is the part in which the extraction process occurs, consists of a glass cylinder, closed at the bottom, from which a narrower cylinder with open end projects downward. The two cylinders are connected by a side tube which opens into the upper portion of each, and also by a siphon which opens from the side of the bottom of the large cylinder, extends upward, then turns upon itself, pierces the middle part of the wall of the lower cylinder, and terminates within and just below its lower end.

When in use, the substance to be extracted is placed within the upper cylinder, upon the bottom of which is placed a wad of absorbent cotton, which prevents the entrance of solid particles to the siphon tube, or it is confined within a cartridge of thick filter-paper which fits loosely within the cylinder. When the cartridge is used, it is best to plug its open end with absorbent cotton, in order to prevent the escape of fine particles of the contained substance.

The three separate parts are joined together and then mounted on a water-bath. The ether or other extracting medium is contained in the flask, the exact weight of which has been determined. The heat of the

water-bath causes the ether to volatilize, and the vapor passes upward through the side tube into the extractor and thence to the condenser, where, coming in contact with the cold surface of the inner tube thereof, it condenses and falls upon the substance to be extracted. As the process continues, the condensed liquid accumulates and gradually rises until it reaches the bend of the siphon, which, when full, begins to act and discharges downward into the flask until the entire liquid is returned to its starting-point. During its accumulation, it acts upon the substance within the cylinder, and extracts more or less of the fat or other substance, as the case may be, which is carried in solution into the flask. The volatilization continues, and the process is repeated again and again as long as is necessary, and in this way the whole of the extracted matter is finally within the flask, since, being itself non-volatile, it remains behind, while the liquid by which it is extracted is sent continually on its errand. On the completion of the process, the ether is sent up again into the cylinder, and before it reaches the level of the siphon the flask is disjointed. The remaining ether is expelled cautiously, and the flask with its contents is placed in an air-bath, maintained at 100° C., and dried until its weight is constant. The increase in the weight of the flask represents the amount of matter extracted.

In determining the fat of milk by this process the method is as follows: To one of the strips of filter-paper, made into a coil, a definite weight of milk, about 5 grams, is applied in either of two ways. A small beaker containing about the required amount is weighed and then the coil is thrust into it, kept there until nearly the whole has been absorbed, and then carefully withdrawn and placed dry edge downward upon a sheet of glass. The beaker is then weighed again, and the loss in weight, which represents the amount of milk absorbed, is noted; or the beaker containing the milk and a small pipette is weighed, and then the necessary amount of milk is transferred to the coil from the pipette, after which operation the weight of the beaker, pipette, and the remaining milk is noted, and the difference set down as the weight of the milk absorbed. The coil is then dried in an air-bath at 100° C. for an hour or more, at the expiration of which time it is ready for insertion into the extractor.

After it has been acted upon by the ether about a dozen times, the flask is detached and treated as above mentioned. After being allowed to cool, the weight is noted and the percentage of fat calculated arithmetically.

Example.—The amount of milk absorbed by the coil was 4.950 grams. The increase in the weight of the flask was 0.173 gram. Then the amount of fat present in the sample is obtained by the equation, $4.95 : 0.173 :: 100 : x$, wherein $x = 3.49$.

2. **The Werner-Schmidt Method.**—In this process, equal volumes of milk and hydrochloric acid, about 100 cc. of each, are mixed in a test-tube and boiled for about a minute and a half, or heated on a water-bath or steam-bath until the mixture is dark brown in color. It is then cooled, and the mixture shaken with 30 cc. of ether. When the

two liquids have separated, the supernatant ether is withdrawn by means of a pipette or blown out with the assistance of a double tube such as is used in wash-bottles, the delivery tube extending into the ether layer very nearly as far as the line of demarcation between the ether and the acid mixture. The operation is repeated with several fresh smaller portions of ether, and the whole of the ether used is collected in a weighed flask. Then the ether is distilled off, and the flask with its residuum of fat is heated to constant weight in an air-bath, cooled, and weighed. The process may be shortened considerably by treating the milk in a graduated tube and, after thorough shaking with ether, removing an aliquot part of the latter by means of a pipette and evaporating to dryness. From the weight of this residue, the amount of fat in the whole volume of ether can readily be determined. Since the milk taken is measured, and not weighed, a correction must be made for gravity.

EXAMPLE.—Amount of milk used = 10 cc. Specific gravity of specimen = 1.032. Weight of milk used = $1.032 \times 10 = 10.32$ grams. Amount of fat found = 0.397 gram. Percentage of fat in the original milk = x in the equation, $10.32 : 0.397 :: 100 : x$; $x = 3.84$.

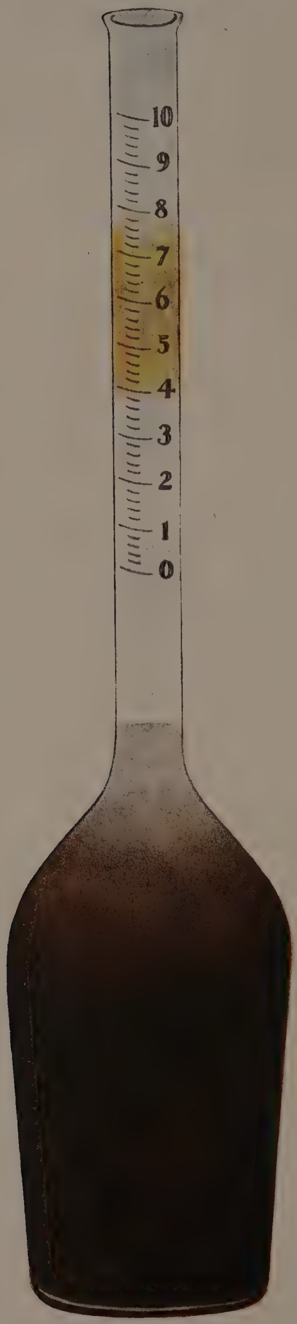
3. **The Babcock Centrifugal Method.**—In this process, equal volumes of milk and sulphuric acid are mixed in flasks of special design with narrow, graduated necks, and then whirled in a centrifugal machine for a definite length of time. On the completion of the process, the details of which are given below, the fat in a pure condition is within the graduated neck, and the percentage is read directly off.

The kind of flask used is shown in Plate III. It has a capacity of about 40 cc. The graduated portion of the neck has a capacity of 2 cc. The details are as follows: 17.6 cc. of the milk are measured by means of a pipette and introduced into the flask. Then an equal volume of sulphuric acid, specific gravity 1.800, is added, and the two liquids are mixed thoroughly by gentle rotary motion. Then the flask is placed in a centrifugal machine made especially for the purpose, and whirled for five minutes, at the expiration of which time hot water is added up to the beginning of the neck. The flask is whirled again for two minutes, and more hot water is added so as to bring the fat layer well up into the neck. After further whirling for one minute, the depth of the fat layer is determined by reference to the scale.

This process gives sufficiently accurate results for all practical purposes, and is in common use at experiment stations in this country. It is much used at creameries for determining the butter value of milk sent in from the surrounding country.

The employment of sulphuric acid having a higher specific gravity than that given, say 1.820, is objectionable in that it frequently happens that it is impossible to obtain a clear fat layer. The fat itself may be turned a very dark color, and the sugar of the milk may be attacked to such an extent that charred portions of it will separate and accumulate within and beneath the column of fat, and so prevent a satisfactory reading. If the acid used is weaker than 1.800, all the casein may not

PLATE III.



Babcock Flask, showing Fat in Neck.

be held in solution, and portions of it may mingle with the fat and destroy the accuracy of the test.

In Plate III. is shown the fat layer in the stem as it should be, free from alteration of color and from charred sugar and particles of casein. It will be observed that the line of demarcation between the water and the fat in the stem is very sharp. For cream, a flask with a much broader neck is employed.

4. **The Babcock Asbestos Method.**—In this method, the dried total solids obtained by the method described below (No. 2) are extracted in a Soxhlet extraction apparatus.

Determination of Total Solids.—1. Weigh into a flat-bottomed platinum dish of about 2 inches (5 cm.) diameter, 5 grams of milk. Place on a water-bath for an hour and a half. Remove to a hot-air bath, maintained at 100° C., until its weight is constant. Cool in a desiccator and weigh. The difference between this weight and that of the dish alone represents the total solids of the amount of milk taken, and, multiplied by 20, expresses the percentage of total solids in the sample. If for any reason it is desired to use the total solids for extraction in the Soxhlet apparatus, the dish may be partly filled before weighing with fine, clean, dry sand, or with freshly ignited woolly asbestos. One objection to the use of the total solids in this way is that it is extremely difficult to remove the whole amount from the dish, to the sides and bottom of which a portion will adhere with great tenacity, and can be removed only by burning. To obviate this difficulty, Dr. C. L. Spaulding has suggested lining the platinum dish with very thin tinfoil, which, after the weight of the total solids has been noted, is withdrawn with the sand or asbestos, and with it inserted into the extraction apparatus.

Formerly, the residue of the milk dried in the dish alone without sand or asbestos was used for the determination of fat by the Wanklyn process, which consists in filling the dish with freshly distilled naphtha or with ether, and allowing it to act upon the residue and dissolve out the fat, several portions being used, after which the dish is dried again and weighed, and the loss in weight taken as the measure of the fat contained. Inasmuch as the solvent cannot penetrate the horny layer which forms on the bottom of the dish, not all the fat can thus be extracted, and the figures obtained are ordinarily about 0.5 too low.

2. **The Babcock Asbestos Method.**—In this process, the milk is weighed into a cylinder of perforated metal or into a filter-paper cartridge filled loosely with freshly ignited woolly asbestos, subjected to a temperature of 100° C. until the weight is constant, and then cooled and weighed. The gain in weight represents the total solids of the amount of milk taken. The cylinder may then be slipped into the extraction apparatus and used for the determination of fat.

3. **Determination of Total Solids by Formula.**—Knowing the correct specific gravity and the amount of fat, it is possible to determine fairly accurately the amount of total solids by the use of the formula of Hehner and Richmond. This formula is as follows: $F = 0.859\ T$

— 0.2186 G, in which F represents fat, T the total solids, and G the figures of the specific gravity beyond the first decimal place.

EXAMPLE.—The specific gravity of a specimen of milk is found to be 1.030, and its fat content 3.95. Then applying the formula, we have

$$3.95 = 0.859\,T - (0.2186 \times 30), \text{ or}$$
$$3.95 = 0.859\,T - 6.558, \text{ or}$$
$$0.859\,T = 6.558 + 3.95 = 10.508, \text{ and } T = 12.23.$$

In other words, multiply 0.2186 by the figures expressing specific gravity, add the percentage of fat to the product, and divide the result by 0.859.

The formula may also be used to determine the percentage of fat, the specific gravity and total solids being known.

Determination of Milk Sugar.—The amount of lactose may be determined either chemically or by means of the polariscope.

1. **Method by Fehling Solution.**—Reagents required: Solution A. Dissolve 34.639 grams of pure sulphate of copper in distilled water and dilute to a liter. Solution B. Dissolve 173 grams of potassium sodium tartrate (Rochelle salt) in distilled water, add 100 cc. of sodium hydrate solution of 1.393 specific gravity, and dilute the mixture with distilled water to a liter.

In making a determination, 10 cc. of each solution are mixed in a boiling flask of about 300 cc. capacity. The amount of copper contained in 10 cc. of solution A requires for its reduction 0.050 gram of dextrose, or 0.0667 gram of lactose.

PROCESS.—Into a porcelain evaporating dish of suitable size, discharge from a pipette 25 cc. of milk. Add three or four times as much water and heat to 40° C. Add acetic acid, a drop at a time, with constant stirring, until the mixture separates into curds and a fairly clear whey. Transfer the whole to a graduated 500 cc. flask, and dilute with water to the 500 mark. Filter a portion through a dry filter, and use the filtrate for titration. Dilute the mixed reagents in the boiling flask with water and boil over a Bunsen flame. From a burette graduated in tenths, add the filtrate from the curds a little at a time, and continue the boiling after each addition. As the blue color begins to appear faint, the addition should be made cautiously, in order not to overstep the end reaction. As soon as the blue color is discharged completely, note the reading of the burette.

The calculation is exceedingly simple. Since 0.0667 gram of lactose is required to reduce the copper in the reagent, it follows that that amount of the substance is contained in the number of cc. of the whey used, and the percentage is obtained by the application of the rule of three.

EXAMPLE.—The color is discharged by 24.3 cc. of the diluted whey. Then in the whole amount of milk taken the amount of sugar will be x in the equation $24.3 : 0.0667 :: 500 : x$. $x = 1.372$. The amount of milk taken was 25 cc., hence in 100 cc. the amount would be 5.49,

and this amount divided by the specific gravity gives the percentage by weight. Supposing the specific gravity to be 1.030, for example, the 100 cc. of milk weigh 103 grams, and the percentage of sugar will be x in the equation $103 : 100 :: 5.49 : x$. $x = 5.33$. Inasmuch as the means of the first equation are constants, the reckoning resolves itself into dividing four times their product, 33.35, or 133.4 by the number of cc. used, and dividing this result by the specific gravity of the specimen.

2. **Method of Polariscopy.**—The determination of lactose and other sugars by means of the polariscope combines the advantages of accuracy and of rapidity. The instruments in common use are of two kinds: those of which the normal sucrose weight, that is to say, the amount of sucrose which, dissolved in water and made up to 100 cc., will show 100 degrees on the scale when observed through a 200 mm. tube, is 26.048 grams, and those in which it is 16.19 grams. Of the former, the Ventzke-Scheibler and the Schmidt and Haensch modification, and of the latter the Laurent instrument, may be regarded as types. The Schmidt and Haensch triple field, half-shadow instrument possesses the advantage of doing away with the matching of colors, and hence may be used by those who are color-blind, and even with those not so afflicted gives, on the whole, the most satisfactory results.

Process.—Into a flask graduated on the neck at 102.6 cc. if the instrument used is one of which the sucrose normal weight is 26.048 grams, weigh 65.95 grams of milk, or into one graduated at 101.6 cc., if it is one of the other class, weigh 40.99 grams, add 1 cc. of solution of mercuric nitrate of pharmacopœial strength, shake well, and dilute with water up to the mark. Filter through a dry filter-paper, fill the 200 mm. observation tube, and note the reading of the scale when the field of observation is uniform. The reading divided by 2 equals the percentage by weight of lactose.

The weights 65.95 and 40.99 represent twice the normal lactose weights of the respective types of instruments. The graduations 102.6 and 101.6 are adopted instead of 100 cc., since the dried precipitated curds from the respective amounts of milk of average specific gravity have a bulk equal to the excess over 100 cc.

Determination of Ash.—The ash may be determined by igniting the residue obtained in the determination of total solids, provided no other substance has been introduced into the dish with the milk. The ignition should be conducted at a low red heat until the ash is perfectly white. Then the dish is cooled in a desiccator and again weighed. The difference between this final weight and the original weight of the empty dish represents the amount of mineral matter in the amount of milk taken. Or a larger amount of milk, say 20 grams, may be evaporated with a few cc. of nitric acid and the residue ignited as above.

Determination of Proteids.—Having determined the total solids, fat, sugar, and ash, the proteids may be reckoned by difference—that is, by subtracting the sum of the fat, sugar, and ash from the total solids, or they may be determined directly by the Kjeldahl process,

which depends upon the conversion of the nitrogenous matter into ammonium sulphate, which then is decomposed by an excess of strong alkali, ammonia being set free. This is expelled by heat, condensed with the accompanying steam, and received in acid of known strength.

The process is as follows: Into a Kjeldahl digestive flask introduce a definite weight, say 5 grams of milk, about 0.7 gram of mercuric oxide, and 20 cc. of sulphuric acid of 1.840 specific gravity, free from nitrates and ammonium sulphate. Place the flask in an inclined position and heat below the boiling-point of the acid for from five to fifteen minutes, or until frothing ceases. Then raise the heat until the mixture comes to boiling, and continue the process until the liquid is clear and has a very pale straw color. This will require ordinarily less than an hour. Withdraw the lamp, and drop in, in small quantities at a time, permanganate of potassium, until, after shaking, the liquid acquires a permanent green or purple color. This addition is not always or even usually necessary to secure complete oxidation, but since it is sometimes required, it is best to make it a part of the routine. Allow the contents to cool, and then transfer them with about 200 cc. of distilled water, plus sufficient for thorough rinsing, to a distilling flask of about 550 cc. capacity, fitted with a rubber stopper and a bulb tube connected with a very long Liebig condenser, the delivery end of which is fitted with a glass tube bent at right angles, so that it may dip beneath the surface of the acid into which the distillate is to be received. Add a few pieces of pumice or granulated zinc, or about 0.5 gram of zinc dust, to prevent bumping, and 25 cc. of a 4 per cent. aqueous solution of sulphide of potassium, to prevent the formation of compounds of ammonium and mercury, which are not wholly decomposable by alkalies. Shake, and then add of a saturated solution of sodium hydrate, free from nitrates, sufficient to make the reaction strongly alkaline, pouring it down the side of the flask so as not to mix at once with the acid contents. Next connect the flask with the condenser, mix the contents by gently rotating, and apply the flame. Distil, and receive the distillate in a vessel containing 50 cc. of decinormal sulphuric acid. When about 175 cc. have passed over, it may be assumed that all ammonia has been expelled, and then the distillate is titrated with decinormal alkali, using cochineal or methyl-orange as an indicator. From the difference in strength of the decinormal acid, the amount of ammonia is calculated, and from this the amount of nitrogen; and this multiplied by 6.25 gives the total proteids.

Detection of Added Coloring Matters.—Annatto.—To about 100 cc. of milk in a cylinder about 1.5 inches in diameter, add a few cc. of sodium carbonate solution, to insure a strongly alkaline reaction during the examination, and then introduce a strip of heavy white filter-paper about 0.5 by 5.5 inches, and set the whole away in a dark place over night. If any annatto color is present, it will, through selective affinity, pass from the milk to the fibre of the paper, which thereby acquires a salmon tint, the depth of which is dependent naturally upon the amount of the substance present. The strip is withdrawn from the

PLATE IV.

A. B.

A. Strip of Filter Paper Dyed by Immersion in Milk Colored with Annatto.
B. Same after Treatment with Solution of Protochloride of Tin.

PLATE V.

FIG. 1.

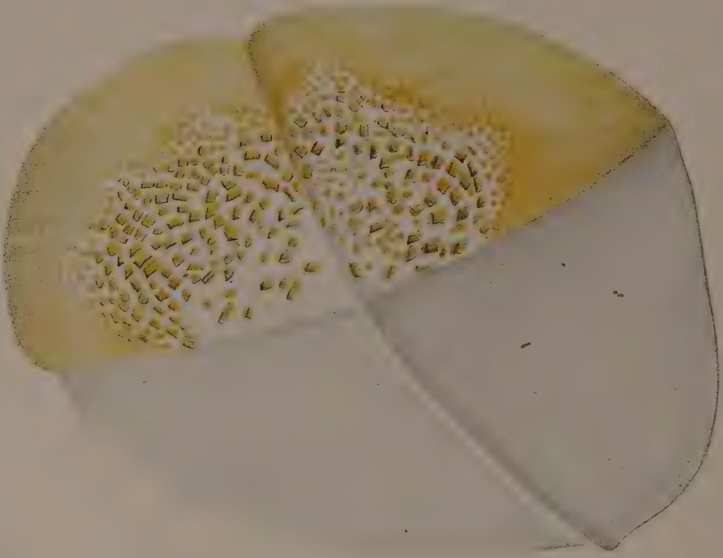


FIG. 2.

Residues Obtained in Testing Milk for Caramel.

Fig. 1. From Uncolored Milk.
Fig. 2. From Milk Containing Caramel.

milk, washed gently in running water, and laid upon a piece of paper of the same kind as itself. If so much as 1 part of the annatto solution in 100,000 is present, the strip will show a distinct salmon tint. On dipping the strip into stannous chloride solution the color is changed to pink.

Another method, by means of which all the color in the amount of milk operated upon may be concentrated in a form best adapted for preservation and for exhibits in court, is as follows: Coagulate from 100 to 150 cc. of the specimen by the application of heat and acetic acid, and separate the coagulum by straining through a piece of cheesecloth. The coloring matter, being insoluble in acid media, is precipitated with the curd, which, however, will show to the eye scarcely any indication of its presence. The curd is placed in a mortar and triturated with 50–75 cc. of ether, which next is transferred to a stoppered separating funnel and shaken with 10 cc. of a 1 per cent. solution of caustic soda. When the two liquids become separated, the latter, which now contains the annatto color, is drawn off into two porcelain or glass dishes about an inch in diameter, in each of which a disk of filter-paper is placed. They are then set aside in the dark and left over night. The disks are then removed and washed in fresh water. If annatto is present, they will have acquired a color varying in depth according to the amount of the dye in the sample. One disk is immersed in stannous chloride solution, the other in weak sodium carbonate, and then dried and mounted on a white card. The colors yielded by a specimen of milk to which no unusual amount of the adulterant has been added are shown in Plate IV.

Caramel.—Pour 125 to 250 cc. of the suspected sample into an equal volume of 95 per cent. alcohol, and filter. The filtrate, if not perfectly clear, should be returned and passed through until it is quite free from turbidity. Any caramel present will be in solution in the alcoholic filtrate, and may modify considerably its color, which normally is yellowish or greenish according to season, the latter obtaining in spring and summer. To 100 cc. of the filtrate add 2 cc. of solution of basic acetate of lead, which will precipitate the caramel together with any remaining proteids, the precipitate showing a slight brownish color if caramel has been used in sufficient amount to bring about the improved appearance which is the object of its employment. Filter, wash with distilled water, and dry in an air-bath. According as the amount of caramel present is large or small, the horny residue on the filter-paper will have a more or less deep chocolate tinge. The residue yielded by a pure milk will be either almost colorless, or yellow, or slightly inclined to brownish, but not to chocolate color. The appearance of the two kinds of residue is shown in Plate V.

Caramel may also be shown if we proceed according to the second method described for the detection of annatto. The curd, after being freed from the whey and triturated with ether, gives up to this solvent only fat and annatto. If caramel or anilins are present, the curd will appear brownish in the one case and more or less intensely yellow in

the other. If the curd is now shaken with hydrochloric acid, one of the following changes will be observed: If anilin-orange is present, the color becomes bright pink almost immediately; with caramel it becomes gradually brownish blue; if neither is present, the change is to blue.

Anilin-orange.—See preceding paragraph. A more direct method is proposed by Lythgoe.[1] Place 15 cc. of milk in a porcelain dish and add about the same volume of hydrochloric acid (specific gravity 1.200). Agitate gently, to bring about thorough mixing and to break up the resulting curd into rather coarse lumps. If anilin-orange is present, the curd will be colored pink; if none is present, it will be white or yellowish.

Detection of Preservatives.—**Borax and Boric Acid.**—These substances are detected easily either in the milk itself or in the ash after ignition of the residue. In the latter case, moisten the ash with a drop or two of strong sulphuric acid, and after a few minutes add 3 or 4 cc. of strong alcohol. Dip a strip of turmeric paper into the mixture and allow it to dry without the aid of heat. In the presence of either of the substances sought for, the paper will have, when dry, the characteristic red color due to boric acid, instead of the yellow color which will be maintained in its absence. While the paper is drying, place the dish in a dark place and ignite the contained alcohol. If boric acid or its sodium compound is present, the flame will show at its outer edge a characteristic greenish coloration. This is shown most strongly directly after the alcohol is ignited.

In the original milk, the test may be made in the following manner: Mix a few drops of the milk and an equal amount of fresh tincture of turmeric in a small porcelain dish and evaporate on a water-bath to dryness. Moisten the surface of the residue with dilute hydrochloric acid, and dry again. If either of the substances is present, the residue will be light pink to dark red in color, and the addition of a drop of ammonia-water will change this to a green or greenish blue, according to the amount of the preservative present.

Salicylic Acid.—1. Coagulate about 75 to 100 cc. of milk with mercuric nitrate solution or hydrochloric acid, and separate the whey by filtration. Shake the whey with ether, decant the ether into a watch-glass, and allow it to evaporate. To the residue on the watch-glass, apply a drop of neutral ferric chloride. If salicylic acid is present, the characteristic purple coloration is produced. 2. Mix the milk with phosphoric acid and strain through cloth. Place the liquid in a flask, connect with a condenser, and distil. Test the distillate with ferric chloride from time to time. Any salicylic acid present will go over with the steam, most of it toward the end of the operation.

Formaldehyde.—Many processes for the detection of this substance in milk have been devised, some exceedingly simple and others quite complicated. Those which give the best results and the greatest satisfaction are, on the whole, those which are the simplest in application

[1] Report of Massachusetts State Board of Health for 1900, p. 647.

and require the least expenditure of time. The test should be applied within a few days after the addition of the preservative, since after a time it cannot be detected.

1. METHOD BY DECOLORIZED FUCHSINE.—Through a solution of fuchsine 1 : 500 pass a current of sulphurous acid gas, obtained by heating copper wire or foil with sulphuric acid, until the color is discharged. Preserve in a glass-stoppered bottle. To 10 cc. of milk, add 1 cc. of the reagent and let stand ten minutes. Add 2 cc. of strong hydrochloric acid and shake or stir briskly. The color which appears in the first instance is discharged completely by the acid if no formaldehyde is present; otherwise, a violet-blue tinge remains. If the amount present is large, the end color will be correspondingly intense. This method will detect the admixture of 1 part of formalin in 50,000 of milk. If the milk be distilled first, and the first part of the distillate treated with fuchsine solution, the test is delicate to the extent of revealing 1 part in 500,000.

2. METHOD BY PHLOROGLUCIN.—Add to 10 cc. of milk in a test-tube 2 or 3 cc. of a 0.10 per cent. solution of phloroglucin and 5 to 10 drops of a 10 per cent. solution of sodium hydrate, and shake. In the presence of formaldehyde a gradual red coloration appears; otherwise, no such change is observed. This test is said to reveal 1 part in 50,000, but such a claim appears, according to the experience of the author and others, not to be justified.

3. METHOD BY FERRIC CHLORIDE.—Mix in a porcelain dish 10 cc. each of milk and hydrochloric acid (specific gravity 1.200) and 1 drop of ferric chloride solution. Heat and stir vigorously. If formaldehyde has been added, a violet color will appear before the boiling-point is reached, varying in intensity according to the amount present. This process is exceedingly delicate, and will detect 1 part in 500,000 in the fresh condition.

4. METHOD BY COMMERCIAL SULPHURIC ACID.—This test is exceedingly delicate and very easily applied. It cannot be performed with pure sulphuric acid, since the presence of a trace of iron is necessary. If one desires to use a pure acid rather than the ordinary commercial grade, the addition of a very small amount of ferric chloride will be sufficient.

Take about 15 to 20 cc. of milk in a test-tube and pour about 5 cc. of the acid gently down the side so that it shall pass under, rather than mix with, the milk. Let stand a few minutes, and then note the color at the junction of the two liquids. If formalin is present, even in the slightest traces, a violet coloration appears at the line of junction. Inasmuch as pure milk will show a somewhat purplish color when in contact with strong sulphuric acid, a color which may readily be mistaken at first for that due to formaldehyde, and since also the charring that occurs at the line of junction will often obscure the reaction, the process as originally recommended is somewhat faulty. The objections are removed, however, by diluting the strong acid with water so that its specific gravity is reduced from 1.840 to 1.700. The action of the

stronger acid on pure milk is shown in Plate VI., Fig. 1, which shows the dark color due to charring and the purplish color, above spoken of, due to the same cause.

In Plate VI., Fig. 2, is shown the appearance of the line of junction of pure milk and the diluted acid. It will be observed that the color produced is but a faint yellow. In Plate VI., Figs. 3 and 4, are shown the zones produced in milk containing formaldehyde in the proportions of 1 part to 25,000 and 1 to 50,000 by the use of the diluted acid. As may be inferred, the reaction is produced rather more slowly with the weaker acid. It is best to allow the contact to continue at least an hour before noting a negative result.

5. LUEBERT'S[1] METHOD BY POTASSIUM SULPHATE.—Place 5 grams of coarsely powdered potassium sulphate in a 100 cc. flask and distribute over it 5 cc. of milk by means of a pipette. Then pour carefully down the side of the flask 10 cc. of sulphuric acid (specific gravity 1.840), and allow the whole to stand quietly. If formaldehyde is present, a violet coloration of the potassium sulphate occurs within a few minutes, and gradually diffuses through the entire liquid. If none is present, the mixture will at once assume a brown color, which rapidly changes to black. This test is sensitive to 1 part in 250,000.

Chromates.—Froidevaux[2] recommends dissolving the ash of about 10 cc. of milk in a few drops of water acidulated with nitric acid and, after neutralizing with magnesium carbonate, adding a few drops of test-solution of nitrate of silver, whereby a red precipitate, chromate of silver, is formed. As a control test, he recommends taking up another portion of ash with water acidulated with sulphuric acid, and adding little by little tincture of guaiacum. In the presence of chromates, an intense blue color is produced, which disappears very quickly. This process will detect 1 part in 50,000. Guerin[3] claims greater delicacy for the following method: To 5 or 10 cc. of milk add 2 drops of a 1 per cent. solution of sulphate of copper and 2 or 3 drops of freshly prepared tincture of guaiacum. Pure milk gives a greenish color, while milk containing 1 part in 100,000 will give an intense blue, which reaches its maximum in a few minutes.

Methods of Distinguishing between Raw and Cooked Milk.—To determine whether or not milk has been cooked, Saul[4] recommends the addition of 1 cc. of a 1 per cent. solution (fresh) of ortol (Orthomethylaminophenol sulphate) to 10 cc. of milk, and then 1 drop of commercial hydrogen peroxide solution. Raw milk develops a red color almost immediately, but milk heated beyond 75° C. remains unchanged.

Dupouy[5] gives the following tests:

1. Guaiacol. Equal volumes of milk and a 1 per cent. solution of guaiacol in water are mixed and then treated with hydrogen peroxide.

[1] Journal of the American Chemical Society, September, 1901, p. 682.
[2] Journal de Pharmacie et de Chemie, 1896, p. 155.
[3] Chemiker Zeitung, 1897, p. 174.
[4] British Medical Journal, March 24, 1903.
[5] Journal de Pharmacie et de Chemie, 1897, p. 397.

PLATE VI.

FIG. 1. FIG. 2. FIG. 3. FIG. 4.

Fig. 1. Coloration Produced by Concentrated Sulphuric Acid, Sp. Gr. 1.840, in Contact with Pure Milk.

Fig. 2. Coloration Produced by Sulphuric Acid of Sp. Gr. 1.700 in Contact with Pure Milk.

Fig. 3. Coloration Produced by Sulphuric Acid of Sp. Gr. 1.700 in Contact with Milk Containing 1 Part of Formaldehyde in 25,000.

Fig. 4. Coloration Produced by Sulphuric Acid of Sp. Gr. 1.700 in Contact with Milk Containing 1 Part of Formaldehyde in 50,000.

The immediate production of a yellow color indicates that the specimen has not been boiled.

2. Hydroquinone. Three cc. of milk are mixed with 1 cc. of a fresh 10 per cent. aqueous solution of hydroquinone and 15 drops of hydrogen peroxide. If the milk has not been boiled, a rose color immediately appears, and in a few minutes green crystals are deposited.

3. Pyrocatechin. Equal volumes of raw milk and an aqueous 10 per cent. solution of pyrocatechin are brought together and treated with hydrogen peroxide. With raw milk a yellowish-brown color is produced; with boiled milk no color appears.

4. α-Naphthol. Raw milk gives with an aqueous solution of α-naphthol and hydrogen peroxide a violet-blue color. Boiled milk gives none.

Storch's method[1] is as follows: To 10 cc. of milk, add 1 drop of a 0.2 per cent. solution of hydrogen peroxide and 2 drops of a 2 per cent. solution of p-phenylenediamin and shake violently. If the milk has not been heated to 78° C. (172.4° F.), an immediate blue color will appear; if it has been heated to 80° C. (178° F.), the blue color appears in about a half minute; and if it has been heated higher than this, the blue will not appear at all. Sour milk should be neutralized with lime-water. Formaldehyde prevents the change to blue, but permits the occurrence of a faint red. The p-phenylenediamin solution keeps, in dark glass, about two months.

Bernstein[2] proposes the following: To 50 cc. of milk, add 4.5 cc. of normal acetic acid, shake gently until coagulation occurs, and filter. Heat the filtrate. If the milk has not been pasteurized, a heavy precipitate of lactalbumin will form. The higher the milk has been heated, up to 90° C. (194° F.), the smaller will be the precipitate; and if it has been heated beyond this, no precipitate at all will form.

Detection of Gelatin in Cream.—For the detection of gelatin in cream, to which it sometimes is added to give it body, Stokes[3] recommends the following procedure: Dissolve a quantity of mercury in twice its weight of strong nitric acid (specific gravity 1.420); dilute with water to 25 times its bulk. To about 10 cc. of this solution add a like quantity of the cream and about 20 cc. of cold water. Shake the mixture vigorously, let stand for five minutes, then filter. If much gelatin be present, it will be impossible to get a clear filtrate. To the filtrate, or to a portion of it, add an equal bulk of a saturated aqueous solution of picric acid. If gelatin be present, a yellow precipitate will immediately be produced. The whole operation is performed in the cold, and if the mercury solution is ready, the test will not take more than ten minutes. Picric acid will show the presence of 1 part of gelatin in 10,000 parts of water.

[1] Zeitschrift für Untersuchung der Nahrungs- und Genussmittel, 1901, p. 898.
[2] Zeitschrift für Fleisch- und Milchhygiene, 1900, p. 80.
[3] The Analyst, December, 1897.

BUTTER.

This valuable milk product is the result of violent agitation of cream until its fat coalesces into granular particles, which are then separated from the residual buttermilk, "worked" to expel as much of the latter as possible, and, with or without the addition of salt and coloring matter, formed into "prints" or "pats," or packed in bulk in boxes and firkins. Its natural color varies with the season, the so-called June butter, made when the cows from whose milk it is produced are feeding on grass, being bright yellow, while that made when they are stalled, and fed on hay and other winter feed, being almost white. The popular demand being for a yellow article the year round, it is customary to secure this color out of season by the addition of annatto and other harmless vegetable coloring agents, the use of which has almost universally the sanction of law.

The flavor is influenced much by the character of the feed, by the care exercised in manufacture, by the amount of added salt, by age, and by the conditions of storage. Like milk, it absorbs odors very readily, both those which improve and those which impair its flavor. Taking advantage of this fact, it is the custom in the valley of the Var and in some other localities to place the freshly made product in proximity to jasmine, violets, tuberoses, and other flowering plants, in order that their fragrance may be absorbed. This practice is known as "enfleurage." The most delicately flavored butter under natural conditions is that to which no salt has been added, but it has the disadvantage that within a short time it acquires a "cheesy" flavor, due to decomposition processes. Owing to its lack of keeping qualities and to the very general preference for a more pronounced taste, the addition of salt in varying amounts is the rule. Butter of good quality has but slight odor, but that which has undergone the common changes due to bacterial action has the characteristic odor and taste of rancidity. This is due to decomposition of the small amount of curd which is entangled in the making, and which cannot wholly be excluded. The fat itself, when separated from the curd by melting, keeps unchanged for long periods. In rancid butter, butyric and other acids are liberated, and others, as formic, are formed by absorption of oxygen. Under some unusual conditions not wholly understood, butter, without becoming rancid in the usual sense, undergoes a change to a perfectly white substance with a marked tallowy odor.

Butter varies considerably in composition, but a fair average may be stated as follows:

Fat	84.00
Water	12.00
Curd	1.00
Salts	2.50
Lactose	0.50

It may be made to contain a much higher percentage of water, with correspondingly less fat.

The fat is composed of glycerides of two groups of fatty acids, which have been mentioned in the description of milk. Those of the insoluble non-volatile acids, oleic, stearic, and palmitic, constitute about 92.25 per cent. of the whole; and those of the soluble volatile acids, butyric, caproic, caprylic, and capric, make up the remainder. It is to the second group that butter owes its distinctive flavor.

The amount of water depends largely upon the thoroughness with which the buttermilk is worked out. In order that more water may be held, and thus a greater profit realized, some makers employ gelatin as an adulterant. One gram of this substance will take up about 10 grams of water, and, when mixed with butter in the right proportion, will hold water in the above ratio without affecting the consistence injuriously. Others employ glucose both for this purpose and as a preservative.

The salts include those natural to milk and those added for the prevention of rapid decomposition. The usual addition is common salt, but the use of boric acid and borax is extending gradually.

Apart from the use of preservatives and of agents to assist in retaining water, butter is not much subject to adulteration, excepting in the sense that substitution of an article of less value when butter is called for is a form of adulteration. This substitute is known variously as artificial butter, butterine, oleomargarine, and margarine. Under the United States statutes, all butter or substitutes therefor made to resemble it, containing fats other than cream, shall be known as oleomargarine.

Following the original process, oleomargarine is made from fresh beef suet, which, after being cooled, washed, and cut into very fine pieces by machinery, is subjected to a temperature of about 110° F. for several hours, in order to separate the fat from the tissue. It is then drawn off and kept for a time at 80° to 90° F., at which temperature the stearin solidifies, and then is separated by pressure from the "oleo-oil." The latter is churned with milk or with milk and genuine butter, colored with annatto, and otherwise treated like butter. At the present time, oleomargarine is made not alone from beef suet, but to a much greater extent from "neutral lard," a product of leaf lard. Cotton-seed oil is used to some extent, but naturally it is not so well adapted to the purpose as the solid fats.

Oleomargarine has been misrepresented to the public to a greater extent probably than any other article of food. From the time of its first appearance in the market as a competitor of butter, there has been a constant attempt to create and foster a prejudice against it as an unwholesome article made from unclean refuse of various kinds, a vehicle for disease germs, and a disseminator of tapeworms and other unwelcome parasites. It has been said to be made from soap grease, from the carcasses of animals dead of disease, from grease extracted from sewer sludge, and from a variety of other articles equally unadapted to its manufacture. The publication of a great mass of untruth cannot fail to have at least a part of its desired effect, not solely on the minds

of the ignorant, but even on those of persons of more than average intelligence. So a prejudice was created against this valuable food product, but it is becoming gradually less pronounced.

The truth concerning oleomargarine is that it is made only from the cleanest materials in the cleanest possible manner; that it is equally as wholesome as butter; and that when sold for what it is and at its proper price it brings into the dietary of those who cannot afford the better grades of butter an important fat food much superior in flavor and keeping property to the cheaper grades of butter, which bring a higher price. Oleomargarine cannot be made from rancid fat, and in its manufacture great care must be exercised to exclude any material however slightly tainted.

Oleomargarine is not and cannot be made from fats having a marked or distinctive taste, and its flavor is derived wholly from the milk or genuine butter employed in its manufacture. It contains, as a rule, less water than does genuine butter, and consequently any difference in food value is in its favor. It undergoes decomposition much more slowly, and, indeed, may be kept many months without becoming rancid. Much has been said concerning its digestibility, and alarmists have gone so far as to claim that it is very indigestible, and likely to prove a prolific cause of dyspepsia, quite forgetting that the materials from which it is made have held a place in the dietaries of all civilized peoples since long before butter was promoted from its position as an ointment to that of an article of food. Many comparative studies have been made on this point, and the results in general have shown that there is little if any difference. H. Lührig[1] has proved by careful experiment that the two are to all intents and purposes exactly alike in point of digestibility.

Oleomargarine has been the subject of a vast amount of restrictive legislation wherever it is made or sold. This has been passed in the interest of dairymen and because of the ease with which it may be sold fraudulently as butter at butter prices. To the practice of fraud in its retail sale, is due very largely the passage of prohibitive laws, many of which, however, have been declared unconstitutional. In Massachusetts, for example, it had at one time a very large sale, and in the city of Boston alone were nearly 200 licensed dealers. But the amount of fraudulent dealing was so great that the Legislature passed an act prohibiting its sale if it contained any ingredient causing it to look like butter; in other words, no annatto or other substance which would cause it to be yellow could be used in its manufacture. Since its natural color is almost white, and since white butter does not appeal to the eye, the result was practically the withdrawal of the article from open sale.

In Germany, on account of fraudulent practices in the adulteration of butter with oleomargarine, the government passed, in 1897, a statute requiring the latter to contain 10 per cent. of oil of sesame, so that any subsequent admixture with butter may readily be detected by Bau-

[1] Zeitschrift für Untersuchung der Nahrungs- und Genussmittel, June, 1899, p. 484.

douin's reaction. This is a red coloration brought about when oil of sesame, furfurol, and hydrochloric acid are brought together; and it is sufficiently delicate to show the adulteration of butter with 2.5 per cent. of oleomargarine containing the oil in the proportion stated. Experiment has shown that butter made from the milk of cows fed on sesame does not yield the reaction, but the fat of the milk of goats fed partly on sesame has been found to give it.

The principal chemical difference between butter and oleomargarine lies in the relative amounts of glycerides of the soluble and insoluble fatty acids. Genuine butter-fat contains nearly 8 per cent. of butyrin, caproin, caprin, and caprylin, while the artificial product contains these glycerides only as they are introduced in the amount of milk or butter with which it is churned, for they are not present in suet, lard, and other animal fats.

Of late years, high-grade butter has found another formidable competitor in what is known variously as renovated butter, process butter, and hash butter. The material from which this is made is gathered from dairies scattered over a wide expanse of country, and differs widely in color, texture, age, and flavor. It is melted, purified of its rancidity by washing, given the desired yellow color, and rechurned.

Butter as a Carrier of Disease.—Since milk is known to be a carrier of the germs of certain diseases under some conditions, the possibility that butter may act in the same way suggests itself, and the more strongly since, in ordinary creaming of milk, all but a very small proportion of the bacteria rise with the cream. Ordinary butter contains millions of bacteria to the gram, but whether the pathogenic forms can long survive has not been investigated very extensively, except in the case of the bacillus of tuberculosis. The bacteria of cholera and typhoid fever have been known to survive several days after being planted in butter, but beyond this we have little knowledge.

Brusaferro, in 1891, produced tuberculosis in a rabbit through the injection of butter made from the milk of a cow with a tuberculous udder. Roth, in 1894, got similar results, and found, moreover, that 2 out of 20 market samples of butter used by him yielded positive results. Schuchardt got negative results from 42 samples, while Obermüller found the bacillus in every sample of Berlin butter used in his first series of experiments. Dr. Lydia Rabinowitsch[1] examined 80 samples obtained partly in Berlin and partly in Philadelphia, and found genuine tubercle bacilli in not a single instance. She did, however, find a spurious organism, which produced in guinea-pigs changes which required very careful examination for the determination of its non-tuberculous character. It was present in 28.7 per cent. of the samples. Petri[2] found it in 37.2 per cent., the genuine bacillus in 32.4 per cent., and neither the one nor the other in 30.4 per cent. Obermüller,[3] using salted butter in a second series, determined that the

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXVI., p. 90.
[2] Arbeiten aus dem kaiserlichen Gesundheitsamte, 1898, p. 27.
[3] Hygienische Rundschau, 1899, No. 2.

injection of the butter-fat itself introduced a cause of irritation, and used, therefore, in his next set the watery fluid separated from the butter by heat and centrifugation. Four samples out of 10 from the same source as his first lot gave undoubted evidence of the presence of genuine tubercle bacilli. Otto Korn[1] found them in 23.5 per cent. of samples purchased in Freiburg, and Dr. C. Coggi[2] in only 2 out of 100 samples purchased in Milan, though in a number of them the spurious organism was present. Morgenroth[3] has subjected oleomargarine to a similar investigation, since milk is used in its manufacture, and has reported positive results from 9 out of 20 samples. Annett[4] examined 28 samples of oleomargarine (15 from Berlin and 13 from Liverpool), and found virulent tubercle bacilli in only 1.

We have as yet no evidence whatever that tuberculosis has ever been spread through the agency of butter, but the subject deserves most thoughtful consideration.

Analysis of Butter.—Ordinarily, the examination of butter is limited to the determination of whether or not it is mixed with or replaced by oleomargarine, but for the determination of its food value it is necessary to ascertain the proportions of fat and water. It is sometimes of interest also to determine the amount of salt and the presence of other preservatives.

Determination of Water.—Weigh a gram or two of the sample into a platinum dish, such as is used in the analysis of milk, and dry to constant weight on a water-bath.

Determination of Fat.—Extract the residue from the preceding determination with ether or freshly distilled naphtha, being careful not to remove any of the particles of curd or salt. The process of extraction is very simple, consisting in filling the dish about half full of the solvent and after a short time decanting it carefully into another vessel, and repeating the operation until nothing is extracted. The solvent, or an aliquot part thereof, may be evaporated in a weighed beaker, or the dish may again be heated to a constant weight and the fat determined by difference. The residue now represents the curd, lactose, and mineral matters.

Determination of Salt, etc.—Ignite this residue at as low a temperature as possible, and thus burn off the casein and lactose. Their combined weight is ascertained by weighing the dish anew. What now remains in the dish is mineral matter, comprising the salts natural to milk and those added. Common salt may be determined by treating the final residue with water acidulated with nitric acid, and titrating in the usual way with standard solution of silver nitrate, using potassium chromate as an indicator.

Another method of determining salt is as follows: Shake a known weight, 5–10 grams, of the sample with hot water in a stoppered sep-

[1] Archiv für Hygiene, XXXVI., p. 57.
[2] Giornale della R. Societa italiana d'igiene, July, 1899, p. 289.
[3] Hygienische Rundschau, 1899, No. 21.
[4] The Lancet, January 20, 1900.

arating funnel until it is melted completely, let stand until the fat gathers on the surface of the water, and then draw off the latter through the stopcock. Repeat the operation with successive portions of about 20–25 cc. of hot water until a few drops of the washings, tested with silver nitrate, fail to show a cloudiness, due to silver chloride. Allow the combined washings to cool, and then, in an aliquot portion, determine the chlorine by standard silver nitrate solution in the usual way.

Determination of the Nature of the Fat.—To determine whether or not a specimen is or contains oleomargarine, an examination of the nature of the fat is necessary. As has been pointed out, genuine butter contains a considerable amount of volatile fatty acids, while the artificial product contains very little; but, on the other hand, the genuine article is correspondingly poorer in the insoluble non-volatile fatty acids. It is upon these differences in the two kinds of fat that the determination of the question of genuineness depends. The usual examination is limited to the determination of the volatile fatty acids in a given weight of the melted fat freed from water, curd, and salt. The fat is saponified, the resulting soap is dissolved in water and then decomposed by means of sulphuric acid, and the volatile fatty acids, thus freed from combination, are then distilled over, and their amount estimated by means of decinormal sodium hydrate. Five grams of genuine butter-fat will yield an amount which will require at least 24 cc. of the alkali for complete neutralization, while an equal weight of oleomargarine yields so small an amount that, as a rule, less than 1 cc. is required. Mixtures give results between these limits, and from them one can estimate approximately the proportion of butter present.

Process.—Heat a small piece of the sample on a water-bath in a suitable beaker until it is melted completely, and the contained water, salt, and curd have collected at the bottom. Decant a sufficient amount of the supernatant fat into a dry filter and allow it to pass into a shallow beaker. When about 10 grams have been collected, place the beaker in a basin containing water and ice, and allow the fat to become hard. Place a small filter paper on one of the pans of the balance and counterbalance it exactly with weights on the other. Then weigh out as rapidly as possible 2.5 grams of the fat, transferring it to the paper by means of a spatula. Place the paper and fat in a 300 cc. Erlenmeyer flask, add 10 cc. of a 20 per cent. solution of caustic potash in 70 per cent. alcohol, and then place the flask on a water-bath. In a short time, especially with gentle rotation of the flask, the fat becomes completely saponified. Continue the heat until the alcohol is expelled, and remove the last traces of the vapor by blowing into the flask with a bellows or by swinging it in the air. Add 50 cc. of hot water, and when the soap is brought completely into solution, add 25 cc. of 10 per cent. sulphuric acid. The latter breaks up the soap, setting free both the soluble and insoluble fatty acids, the latter in the form of curds. Connect the flask with a Liebig condenser, after introducing several pieces of pumice stone to prevent bumping, and then, with the flask supported on a square of wire netting over a Bunsen lamp, distil

slowly until 50 cc. have been collected. Titrate the distillate with decinormal sodium hydraté, using phenolphthalein as an indicator. With the amount of fat taken, at least 12 cc. of the alkali will be required for neutralization, if the specimen is genuine butter.

Many analysts prefer to employ 5 grams of fat and correspondingly larger volumes of water, and to distill 110 cc., whereof 100 is titrated. Some prefer also to carry on the process of saponification in a round-bottomed flask under pressure. Some measure the fluid fat directly into a weighed flask from a pipette, and ascertain the amount taken by re-weighing after the fat has cooled and solidified. The saponifying agent is applied in different forms, and many other variations in detail are recommended, but the end result is practically the same. The process described has been found in the experience of the author to be most satisfactory.

The Leffmann-Beam process has much to recommend it, particularly in the saving of time. The saponifying agent is prepared by mixing 20 cc. of 50 per cent. caustic soda solution and 180 cc. of pure concentrated glycerin. To 5 grams of fat in an Erlenmeyer flask add 20 cc. of this solution, and then heat over a Bunsen flame until saponification is complete. This requires but a few minutes; the completion of the process is shown by the clear condition of the mixture. The soap is diluted with 135 cc. of boiled water, added at first in very small amounts to prevent foaming. Then 5 cc. of dilute sulphuric acid (200 cc. in 1000) are added, and the preparation is ready for immediate distillation. Distil 110 cc., mix thoroughly, and pass through a dry filter, titrate 100 cc., and to the result add $\frac{1}{10}$ for the remaining 10 cc.

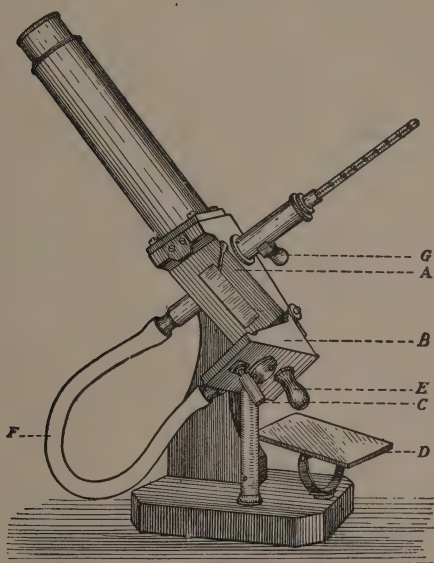
If one wishes to determine the amount of insoluble fatty acids, it may be done in the following manner, but it should be said that the process requires much more time, and that the results are not always satisfactory, since the upper limit in the case of butter is so near the lower limit in that of olemargarine that samples yielding results close to the dividing line may need further analysis before an unqualified opinion of the nature of the specimen can be given. A mixture of genuine butter and oleomargarine may give results well within the normal limits of butter.

Process.—Into a weighed beaker decant a few grams of the fat, and, when the latter has cooled, ascertain the amount taken by reweighing. Saponify as above described, evaporate the alcohol, dissolve the soap in water, and decompose it by the addition of an excess of acid. Heat until the precipitated insoluble acids are melted, then allow the whole to cool. When the fatty layer has assumed the character of a solid crust, break a small hole through it at a point on its circumference and another on the opposite side. Weigh a funnel and a dried filter of suitable size, place the latter within the former, wet it thoroughly, and then filter the liquid from beneath the crust. Break up the crust, add boiling water, and transfer the whole to the filter. Wash repeatedly with boiling water until the washings have no longer an acid reaction, then let drain until no more water is discharged. The filter-paper

being wet, the melted fatty acids do not pass through with the washings. Place the funnel and its contents in the beaker and dry in an air-bath at 100° C. to constant weight. The increase in the combined weights of the beaker, funnel, and paper represents the amount of insoluble fatty acids in the amount of fat taken.

Examination of Fat by Means of the Butyro-refractometer.—A simple and quick method of ascertaining the nature of butter-fat without recourse to chemical analysis is that by means of the butyro-refractometer or other instrument designed for the purpose of measuring the refractive index. The instrument is shown in Fig. 4, with the prism

Fig. 4.



Zeiss butyro-refractometer.

casing wide open. Its application requires so little time that, after a little practice, a person working alone can examine readily 15 or 20 samples in an hour. The method of use is as follows: The surface *A* and that to which it is opposed when the prism casing is closed should first be cleaned by means of a soft piece of linen moistened with alcohol or ether. Place the instrument so that the surface of the prism *B* is horizontal, then apply 2 or 3 drops of the clear fat, best from a small filter paper held between the fingers. Close the prism casing and fasten it by means of the pin *C*. The surfaces of the two prisms are now separated from each other only by the very thin layer of fat. With the instrument in its original position, the mirror *D* adjusted so as to illuminate the field clearly, and the upper part of the ocular so adjusted that the scale within is most clearly defined, read off at what point of the scale the line between light and shade falls. Since the degree of

refraction is influenced by the temperature, it is necessary to have some means of determining accurately the temperature of the specimen between the prisms. This is secured in the following manner: A current of warm water is conducted by means of a rubber tube connected with the inlet *E* into the prism casing, thence through the rubber tube *F* to the upper part, from which it escapes through the outlet *G*. The bulb of a thermometer projects into the current of water. The standard temperature for observations with this instrument is 25° C., and at this temperature natural butter, which has a refractive index of 1.459–1.462, will give a reading of from 49.5 to 54 on the scale, while oleomargarine, which has a refractive index of 1.465–1.470, will show 58.6 to 66.4, and mixtures of the one with the other will give from 54 upward, according to the percentage of oleomargine present.

According to Wollny, to whom the invention of the instrument is largely due, any specimen which at a temperature of 25° C. gives a higher reading than 54 will invariably be found on chemical analysis to be adulterated; but he suggests that, in order to remove all chance of adulterated butter escaping detection, this limit be reduced to 52.5, and that all samples giving the latter reading be examined chemically.

With temperatures other than 25° C., it is necessary to make corrections of 0.55 of a scale division for each degree C. The following table shows the maximum reading for pure butters at different temperatures:

Temp.	Sc. div.	Temp.	Sc. div.	Temp.	Sc. div.	Temp.	Sc. div.
25°	52.5	31°	49.2	37°	45.9	43°	42.6
26	51.9	32	48.6	38	45.3	44	42.0
27	51.4	33	48.1	39	44.8	45	41.5
28	50.8	34	47.5	40	44.2		
29	50.3	35	47.0	41	43.7		
30	49.8	36	46.4	42	43.1		

There are other processes for the investigation of the character of butter-fat, including the determination of the specific gravity, melting-point, iodine absorption number, and saponification equivalent; but for all practical purposes the determination of the refractive index or of the volatile fatty acids is ordinarily sufficient, and the other determinations are merely corroborative.

CHEESE.

For thousands of years, cheese has been known as a very valuable food, and much attention has been paid to different methods of manufacture. At the present time, many varieties are made, their nature depending upon that of the raw material, the method of producing the curd, the proportions of the several constituents, and the method of ripening. Most varieties are made from cows' milk; some are made from that of ewes, and others from that of goats.

The milk is used either in its natural condition, or skimmed, or with the addition of cream. Generally, it is used in its natural condition. Whatever the kind, the following is the general process of manufacture. The milk, with or without coloring matter as desired, is heated to 80° F. or above, and then curdled by means of rennet or by the acids formed by the ordinary milk bacteria. Usually, rennet is employed; sometimes, sour whey. The coagulation should be complete in from forty minutes to an hour. Too rapid coagulation causes the curd to be hard, tough, and unsuitable for the subsequent manipulation; too slow action produces a soft curd difficult to work and not uniform in character. After the process of coagulation is complete, the curd is cut or broken into small pieces, and the whey is drawn off. Then the curd is gathered into a heap and covered, and allowed to stand for an hour or longer, during which time its increasing acidity assists in its hardening and promotes the separation of the remaining whey. When the curd has attained the proper consistence, it is placed in a cheese press and subjected to gradually increasing pressure, and after this process is completed it is removed to the curing place. For the proper ripening of cheese, it is essential that the curd be of the proper consistence throughout, and that only the favorable organisms be present, and these in not too great abundance.

The curd produced by the action of sour whey is highly acid and inclined to be greasy. Owing to its high degree of acidity, it is not a favorable ground for the growth of many of the bacteria to which is due the production of the different kinds of flavor, and so the number of varieties possible of manufacture by sour whey is limited. Rennet, on the other hand, produces a curd which is elastic and not greasy or sticky, and which is a good culture medium for the bacteria whose assistance is needed. It acts best in milk which is slightly acid, for if the milk is neutral or only very slightly acid, the coagulation proceeds very slowly and the curd will not contract sufficiently to expel the whey; if the milk is too acid, the process of coagulation is too rapid and the product too tough. A soft curd retains too much whey, and the fermentation of the milk sugar of the whey causes "huffing," or swelling, for the prevention of which, preservatives sometimes are employed. The bacteria concerned in the process of ripening exist in the original milk or in the air of the place of manufacture. Sometimes the varieties which produce cheese "faults" gain a foothold on the premises, and can be eradicated only by means of thorough cleaning and disinfection. The ripening process is carried on at about 70° F. It is essentially a process of decomposition, in which enzymes, bacteria, and moulds are concerned; and for the production of the same kind of cheese the same varieties of organisms must be present, and the particular variety producing a particular flavor must find the conditions such as are favorable to its predominance. It is not possible to start with milk that is entirely sterile, and then to inoculate with the particular varieties wanted, since to sterilize milk completely requires the application of such a degree of heat as will produce changes in the

casein, interfere with the proper action of the rennet, injure the consistence of the curd, and destroy the enzymes.

Ripening does not proceed satisfactorily when the curd has been produced through the action of acids. In ordinary ripening, the casein is attacked by the organisms present, and ammonia, leucin, tyrosin, and several kinds of fatty acids are produced. The latter unite with the lime salts, which up to this point have been in combination with the casein. The acids formed include butyric and valerianic. From the lactose, we have, in addition, lactic acid. The process goes on at different rates with different kinds of cheese, and it may be short or long. In the production of certain forms of American and English cheeses, the individual specimens are sealed hermetically in tin boxes and kept at a favorable temperature for as long as four years, the boxes being turned each day. The ordinary grades of cheese, however, undergo comparatively short periods of ripening.

Composition of Cheese.—The composition of cheese varies very much according to the nature of the raw material and the process of manufacture. The fat shows the greatest variation in amount, according as the cheese is made from whole milk, skimmed milk, or milk enriched with cream. The most common American cheese is made from whole milk, as are also the leading varieties of English cheese, as Cheddar and Cheshire. The familiar Edam (Dutch) cheese is made from partially skimmed milk. English Stilton is a type of cheese made from milk enriched with cream. The cheese richest of all in fat is what we know as cream cheese, but, strictly speaking, this is not cheese at all, being simply fresh curd very rich in fat and not subjected to any process of ripening. The cheeses poorest in fat are those made from skimmed milk. They are tough, dry, and of but little flavor, and such as they have is inclined to be unpleasant. American cheeses of good quality may be said in general to contain about 36 parts of fat, 30 of proteids, 30 of water, and the remainder salts. The leading English cheeses, excepting Stilton, contain rather more water (about 35 per cent.), and correspondingly less fat. Swiss cheese has practically the same composition, but contains rather more proteids and correspondingly less fat. Skimmed milk cheeses are particularly rich in proteids, containing often as high as 50 per cent. With the exception of those made from skimmed milk, it may be said in general terms that cheese is about one-third fat and one-third proteids.

Of the many varieties of cheese put up in small bulk, mostly for use as a relish rather than as a substantial article of diet, the following may be mentioned: Roquefort is made from the partly skimmed milk of ewes; it does not vary much in its percentage of fat and proteids from American and English cheeses. Gorgonzola is very similar to Roquefort in composition and also in the method of manufacture. Both are ripened with the assistance of moulds, which are mixed with the curd with the powdered bread crumbs on which they have been cultivated, and the cheeses are inoculated also after being shaped. Parmesan cheese is made from partly skimmed goats' milk; it is very rich in

proteids but contains only about half as much fat as American cheese. Camembert cheese is a soft cheese containing rather more than 50 per cent. of water and about 20 per cent. each of fat and proteids. It is ripened by a peculiar process which gives it a much more pronounced and permeating odor than almost any other known variety.

Adulteration of Cheese.—At the present time, the only extensive form of adulteration of cheese consists in the substitution of lard for the usual and proper kind of fat. Lard and skimmed milk colored with annatto are mixed together, heated to about 140° F. in tanks, and emulsionized with the assistance of appropriate machinery; the mixture then is coagulated in the same way as in the ordinary process of making cheese. Such cheese is designated in the United States statutes as "filled cheese," which includes "all made of milk or skimmed milk with the admixture of butter, animal oils or fats, vegetable or any other oils, or compounds foreign to such milk."

A decree promulgated in Belgium on September 21, 1899, defines cheese as a product obtained from pure milk, skimmed milk, milk coagulated by the aid of rennet or acidification, or any other product obtained by heating milk mixed or not with coloring matter, salt, and spices, and subjected to pressure and fermentation. It forbids the sale, except when properly labelled in such way as to reveal its true nature, of all cheese containing any other substance than those mentioned, such as oleomargarine or other foreign fat, potatoes, and bread. An exception is made, however, in favor of Roquefort, in which bread crumbs are present, not as an adulteration, but for the serving of a useful purpose. The sale of cheeses mixed with mineral matter other than salt and with antiseptics in general is forbidden.

In some parts of Germany, bean meal and potatoes are used to some extent as adulterants, and there and elsewhere a great variety of substances are said to have been used to a greater or less extent in times gone by. In general, it may be said that, aside from lard and other foreign fats, the only adulteration of any importance consists in the admixture of preservatives. These are added more commonly to skimmed milk cheeses than to those of good quality.

Analysis of Cheese.

Determination of Water.—Cut the specimen into small bits or thin slices. Weigh out about 5 grams in a platinum dish containing sand or asbestos fiber, and dry to constant weight.

Determination of Ash.—Ignite the dried residue at as low a temperature as possible, and, after cooling, note the increase in weight over that of the dish and its original contents.

Determination of Fat.—Triturate about 25 grams of the specimen in a mortar with an equal bulk of fine beach sand. Transfer the whole to a Soxhlet extractor, and proceed in the manner described under the Analysis of Milk.

Determination of Proteids.—Proceed in the manner given under Analysis of Milk, using about 2 grams of the sample.

Determination of the Nature of the Fat.—For the detection of foreign fats, the method of procedure is the same as described under the Analysis of Butter, after obtaining the fat in a pure condition. The residue obtained in the determination of the amount of fat will serve for this purpose.

Cheese as a Cause of Poisoning.

For many years, cheese has been known to be an occasional cause of single and multiple cases of poisoning, and various theories concerning the nature of the poisonous agent have been promulgated. It was not until 1884 that the cause was revealed by Professor V. C. Vaughan, whose attention was drawn to outbreaks in Michigan during 1883 and 1884, in which more than 300 persons were affected. He traced the whole trouble to twelve different cheeses, from several of which he isolated the poisonous principle, a ptomain, to which he gave the name "tyrotoxicon." The symptoms observed in the outbreaks referred to included vomiting, diarrhœa, abdominal pain, dryness and constriction of the throat, feeble and irregular pulse, and marked cyanosis. In some cases, vomiting and diarrhœa were followed by marked nervous prostration. In some the pupils were dilated.

Within a short time after Vaughan's discovery, the poison was found by Wallace[1] in some cheese that was the cause of poisoning of not less than 50 persons out of about 60 who had eaten of it. The onset appeared in from two to four hours. The most constant and severe symptoms were vomiting and chills. These were succeeded by severe epigastric pain, cramps in the legs and feet, purging and griping, numbness especially marked in the legs, and very marked prostration. Vomiting and diarrhœa lasted from two to twelve hours; chills and cramps from one to two hours. No deaths occurred, and all recovered within three days. The severity of the symptoms bore no relation to the amount eaten; some of the severest cases were of persons who ate but sparingly.

More recent work by Vaughan and his associates and others has demonstrated that tyrotoxicon is not the only cause of cheese-, milk-, and ice-cream-poisoning, and that it is, indeed, a somewhat rare poison. Other toxic substances have been isolated from cheeses that yielded no tyrotoxicon.

Section 4. VEGETABLE FOODS.

The vegetable foods may conveniently be divided into several classes as follows:

1. Farinaceous seeds:
   (*a*) Cereals; (*b*) Legumes.
2. Farinaceous preparations.
3. Fatty seeds (nuts).
4. Vegetable fats.

[1] Medical News, July 16, 1887, p. 69.

5. Tubers and roots.
6. Herbaceous articles ("vegetables").
7. Fruits used as "vegetables."
8. Fruits in the narrower sense.
9. Edible fungi.
10. Saccharine preparations.

The words *fruit* and *vegetable* are capable alike of broad and narrow meanings. In the strict sense, the cereals, legumes, nuts, and many of the articles commonly called vegetables are fruits; but popular usage has narrowed the latter term to include the pulpy substance enclosing the seeds of various trees and plants, and only such as are pleasant to the taste and edible in the raw state, with the single exception of the quince, which is edible only when cooked. Vegetables in the ordinary sense include any part of herbaceous plants, as the stem, root, leaves, and fruity products used commonly in the cooked state or in the form of salads. Thus, in the popular usage of the terms, squashes and melons, which are the fruits of plants of the same family, are classed respectively as vegetables and fruits, and the cereals and nuts are classified under neither head.

First in importance of vegetable foods are the farinaceous seeds; they are of very high nutritive value and easily digested.

1. Farinaceous Seeds.

(*a*) CEREALS.

The cereals include wheat, rye, barley, oats, corn, buckwheat, and rice. They are very largely starchy, and agree in general composition; but they differ in the proportions in which their several constituents are present. These include proteids, carbohydrates, ether extractives, mineral matter, and moisture. The proteids include a large number of closely related compounds, as yet only imperfectly studied, which will be mentioned in the consideration of each member of the group. The carbohydrates include those which are soluble, sugar and dextrin, and those which are insoluble, starch, cellulose, pentosans, and gelactans (H. W. Wiley). The ether extractives include fats, resins, chlorophyll, and volatile oil "which constitutes the source of the odorous quality possessed by the grain" (Wiley). The mineral matters are chiefly phosphates of calcium, and magnesium, silica, and salts of sodium and potassium. The cereals contain also certain ferments, the most important of which, and the only one which has been studied with any thoroughness, is diastase. This acts upon starch, converting it into sugar. The others include some which act upon the proteids.

Wheat.

Wheat is classed very properly as the most useful of the vegetable foods. The grain consists of a hard outside layer which is indigestible and useless as food, and the cortex, softer and more friable,

which yields flour of high nutritive value. The hard outside layer, which constitutes the greater part of bran, irritates the alimentary canal, and, while useful to some extent in conditions of habitual constipation, should be avoided in all irritable conditions of the bowel. It causes waste by unduly promoting peristalsis, so that much of the nutritive portion is hurried along in an undigested condition.

The proteids of wheat include, according to Osborne and Voorhees,[1] a globulin, an albumin, a proteose, gliadin, and glutenin. The two last-mentioned constitute between 80 and 90 per cent. of the whole; in the presence of water they unite to form the very important substance gluten, so essential in the conversion of flour into bread. According to Wiley, they unite in almost equal proportions; but in the opinion of E. Fleurent,[2] the closer the composition of gluten approaches the relation of 25 parts of glutenin to 75 of gliadin, the more valuable the flour.

The carbohydrates constitute the greater part of wheat as well as of the other cereals. They include starch, by far the most important, cellulose, sugars, dextrin, and a number of other compounds of comparative unimportance. The starch granules are exceedingly variable in size, ranging from about 0.002 to 0.05 mm. in diameter. They are circular and flat, and many of them show a central hilum and concentric rings. The latter appear with greater distinctness in flour that has been subjected to heat, as, for instance, in the baking of crackers. The wide variations in size are illustrated in Plate VII., Fig. 1. The other carbohydrates exist in but very small proportions.

Composition of Wheat.—The vast number of analyses of wheat show important variations in the percentage of its several constituents, for its quality is influenced considerably by climate, character of the soil, and other conditions. According to H. W. Wiley,[3] a typical American wheat of the best quality should yield approximately the following results:

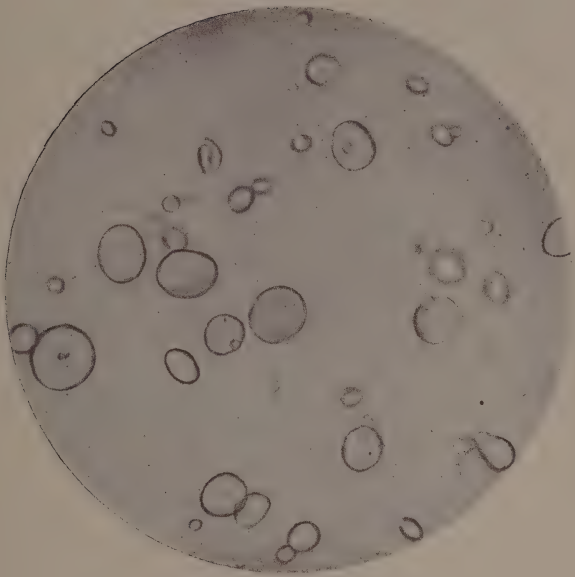
Moisture	10.60
Proteids	12.25
Ether extract	1.75
Crude fiber	2.40
Starch, etc.	71.25
Ash	1.75
	100.00

These figures do not vary materially from the averages of a large number of analyses of samples of miscellaneous origin compiled by König, excepting in the proportions of moisture and starch, in which respects Wiley's typical specimen shows superior value, being less rich in the one and richer in the other constituent.

[1] American Chemical Journal, XV., p. 392.
[2] Comptes rendus, 1898, p. 126.
[3] U. S. Department of Agriculture, Division of Chemistry, Bull. 13, Part 9, p. 1189.

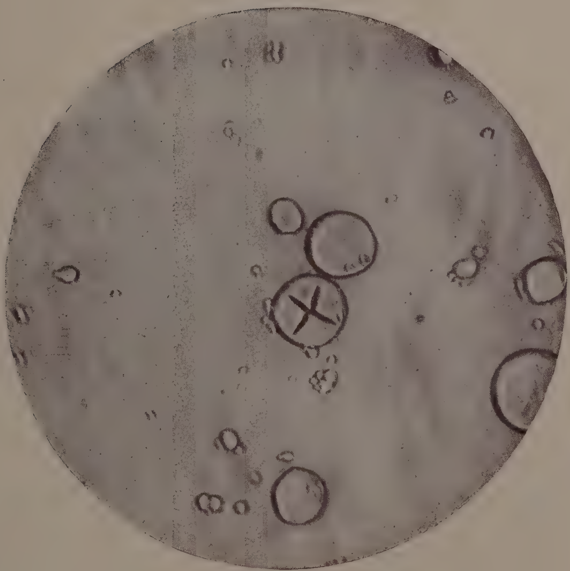
PLATE VII.

FIG. 1.



Wheat Starch. × 285.

FIG. 2.



Rye Starch. × 285.

Wheat Flour.

In the manufacture of flour, the wheat kernels are subjected first to a process of thorough cleaning, and then are cracked, crushed, and ground until the required state of fineness is attained, the bran and other undesirable portions being removed by bolting. All flour is by no means the same in composition and quality; in fact, several grades of flour may be made from the same wheat by the employment of different processes of manufacture. Flours are graded according to color or appearance, those which make the whitest bread ranking highest, although not equal in nutritive value to those classed as low grade. The flours of the several grades are known commercially as "patent," "family," "bakers'," and other names which to the public have no special significance. Typical flours of the grades known as "high-grade patent" and "bakers'" should have, according to Wiley, approximately the following composition:

	Moisture.	Proteids.	Ether extract.	Carbohydrates.	Ash.
Patent	12.75	10.50	1.00	75.25	0.50
Bakers'	11.75	12.30	1.30	74.05	0.60

The average composition of 210 samples of wheat flour of high and medium grades and of grades not indicated is, as given by Atwater and Bryant, as follows:

Moisture	12.00
Proteids	11.40
Ether extract	1.00
Carbohydrates	75.10
Ash	0.50
	100.00

Thirteen samples of low grade averaged as follows:

Moisture	12.00
Proteids	14.00
Ether extract	1.90
Carbohydrates	71.20
Ash	0.90
	100.00

It will be noticed that the high grade flours are poorer in proteids and fat, and correspondingly richer in starch. Other grades of flour include those known as graham and entire wheat. Graham flour is understood generally to be a product containing all of the constituents of the original grain in their same proportions. When it came first into use, such, indeed, it was; but at the present time it is an unbolted or partially bolted product of thoroughly cleaned and dusted wheat. Entire wheat flour is understood also to contain all of the original constituents of the grain, but is, in fact, made from wheat deprived of its outer coverings. It makes a somewhat dark-colored bread which is very palatable.

Parenthetically, it may not be out of place to refer here to the absurd views maintained by a large part of the community as to

the superiority, from a hygienic standpoint, of foods containing all of the constituents of the cereals from which they are prepared. It is difficult to understand how the nutritive value of any food can be increased by the retention of matters which are completely indigestible and to a certain extent irritating to the digestive tract. It is argued that an all-wise Creator made wheat, for example, in the form in which we see it, and that it is not for us to attempt to improve it, as we think, by discarding the outer layers. But this sort of reasoning might be extended so as to favor the consumption of the peel of oranges, the bones of fish, the feathers of birds, and other innutritious and undesirable waste products.

Preparations of Wheat Flour.—Bread.—First in importance of the preparations of wheat flour is bread. In the broad sense, bread includes all forms of baked flour, whether leavened or unleavened; in the common use of the term, it includes only those in which leavening agents are used, the other forms being designated as pilot bread, crackers, biscuits, etc.

The adaptability of wheat flour for bread-making is due to its gluten content. This substance, by reason of its tenacity, is capable of entangling the gas generated in the process, and by reason of its solidification by heat, furnishes a porous or spongy product easily penetrated and acted upon by the gastric juice. Not all cereals are capable of being made into bread, since, as will be seen, in most of them this very essential agent is lacking.

For the preparation of bread of good quality, the flour should contain not much in excess of the average amount of moisture, and should be so cohesive that, after being compressed in the hand, it will keep its shape on being released.

In the making of bread, the flour is mixed with warm water or milk, salt, and yeast, kneaded into a stiff dough, and set aside in a warm place. The yeast attacks the sugar and splits it into alcohol and carbonic acid gas; the latter by its evolution and expansion causes the dough to become porous and to "rise." The fermentative process gives rise also to variable amounts of lactic and acetic acids. The raised dough is then baked in suitable pans, and its porous character is increased by the further expansion of the gas by heat and is made permanent by the solidification of the gluten by the same influence. If the fermentation is not allowed to proceed far enough, the resulting bread will be soggy or "heavy"; if too far, it will be sour.

In place of yeast as a leavening agent, bicarbonate of sodium, commonly known in the household as saleratus, and baking powders are employed very extensively. For the evolution of carbonic acid gas from sodium bicarbonate, the presence of an acid is necessary, and this is secured by the use of sour milk. First, the flour is mixed thoroughly with the bicarbonate and then made into a dough with the milk. Bread made by this process is rarely of good quality, since it is difficult to determine the proper amounts of the two agents for the best results, and any excess of the bicarbonate causes discoloration and disagreeable

flavor. A better plan is to employ baking powder, which consists of sodium bicarbonate and an acid salt combined in such proportions that all of the available gas is set free from the alkaline salt and no unpleasantly tasting residue is left. The only advantage possessed by baking powders is the saving of time and labor; the resulting bread is distinctly inferior to that made with yeast. The composition of the various classes of baking powders will be stated farther on.

Another process of securing leavening is that of spontaneous fermentation brought about by the enzymes present normally in flour. This process, known as "salt rising," is not in common use, requires much more manipulation than any other, possesses no advantages, and, therefore, deserves no further mention.

Freshly baked bread is much less digestible than that which has been kept a day or two. Its softness favors its clogging during mastication into a close mass which is attacked less easily by the gastric juice. In this country, however, it is the almost universal custom to eat bread, particularly in the form of breakfast rolls, not only in the fresh condition, but also hot from the oven. When bread is kept for a day, it loses part of its moisture and acquires increased firmness and friability, which help maintain its porosity during mastication.

Bread may acquire unwholesome properties on keeping, due to changes brought about in the presence of moisture by micro-organisms. Good bread is only slightly acid; but if kept in a moist state, it is likely to become markedly so, and then may cause gastric derangement and diarrhœa in those not habituated to its use. Bread in this condition is undergoing fermentative changes that are hastened by the body temperature, with consequent evolution of gaseous products which cause flatulence and discomfort, and of irritating compounds which induce abdominal pain and diarrhœa. Bread made from old and partially spoiled flour is likely to have a distinctly sour taste and to be unwholesome in the manner above described. Mouldy bread also is likely to be a cause of digestive derangement.

Composition of Wheat Bread.—Since wheat flour itself is of variable composition, and since in the domestic manufacture of any article of food the processes employed are subject to slight or considerable variations, analyses of wheat bread necessarily must show great differences in the proportions of the several constituents. Averages obtained from examination of samples of all sorts and of miscellaneous origin can hardly represent the composition of bread of good average or high quality. Wiley gives the following as the approximate composition of a "typical American high-grade yeast bread made with the best flour and in the most approved manner:"

Moisture	35.00
Proteids	8.00
Ether extract	.75
Ash	1.50
Fiber	.30
Carbohydrates, other than fiber	54.45
	100.00

From analyses of bread made from three sorts of flour from the same lot of wheat, namely, "graham," "entire wheat," and "patent," Professor H. Snyder[1] shows that the nitrogen content is highest in graham and lowest in patent flour; but his digestion experiments prove that the latter has the highest proportion of digestible (available) protein. The lower digestibility of the protein of the others is due to the fact that both have a considerable proportion of that constituent in the coarser particles (bran), and that these resist the action of the digestive juices and escape digestion, so that the system derives less energy therefrom.

Toast.—In the process of toasting, a large part of the moisture is driven off, the surfaces are scorched, greater firmness is acquired, and the product is more easily digestible. Good toast cannot be made from perfectly fresh bread, on account of the moisture present, which causes sogginess; it can be made only from bread at least a day old. The slices should not be thick, since then, while the surface is scorched, the interior acquires increased softness under the action of heat and becomes less digestible than the original bread.

Rusks are much like toast. Instead of being subjected to the direct action of hot coals, the bread slices are baked for a time in a moderately hot oven.

Pulled Bread is the crumb of freshly baked loaves pulled out in small masses and baked again like rusks.

Crackers, or **biscuits,** are preparations made from unleavened dough and baked so dry as to be brittle. They keep well for a long time without losing their palatability. If not properly stored and cared for, they may, of course, become damp, musty, and mouldy. In composition they vary but little from the flour of which they are made; they are drier, and what they lack in moisture they make up in fat, which, in the form of butter or lard, is added to prevent them from becoming too hard and dry.

Other preparations of wheat flour include cakes, which, on account of the contained butter, eggs, and sugar, are richer than bread; pastry, which, on account of its content of lard, is more difficult of digestion; and flour puddings, which, being very "close," require much time for digestion and often cause sensation of weight and oppression.

Macaroni, spaghetti, and **vermicelli** are preparations made with hard wheat rich in gluten. The flour is made into a stiff paste with hot water, and the compound then is pressed through holes or moulds in a metal plate and dried. They are exceedingly nutritious, but they are not as easy of digestion as other preparations of wheat, on account of their closeness. They were first made on a small scale in Sicily, but now are produced in enormous amounts in Italy, France, Germany, and other countries. In their manufacture, American wheats are not held in high esteem, containing not sufficient gluten and too much starch. The best wheat for the purpose comes from a particular district in

[1] Bulletin No. 101, Office of Experiment Stations, U. S. Department of Agriculture, 1901.

Russia and from Algeria. Formerly, a grain from southern Italy was regarded as the most suitable.

Adulteration of Flour.—Up to within comparatively recent years, flour has not been much subject to adulteration. Occasionally, certain mineral substances, as magnesium carbonate, gypsum, and ground chalk, have been reported in European samples; but such have been employed as adulterants very rarely, if, indeed, at all in American flours. Alum has been added sometimes to flour of inferior quality to improve its color or to check beginning decomposition. Whether this addition is objectionable from a hygienic standpoint is a subject over which there is decided disagreement. It is believed by some that the amount of alum added is sufficient to exert an injurious effect on the digestive tract on account of its astringent action, and to bring about constipation and dyspepsia; others believe that it can do no harm whatever, either to the consumer or to the nutritive value of the food; and still others hold that, while it is not injurious to health, it lessens the nutritive value of the flour by forming insoluble aluminum phosphate, and thus depriving the system of the phosphates which otherwise would be absorbed. It is a fact that flour, treated with alum on account of beginning deterioration, has caused untoward effects, but it would be impossible to determine how much influence should be ascribed to the alum and how much to the products formed by the fermentative processes in operation before the addition. The weight of evidence, however, is in favor of the view that alum is not incapable of producing injury when taken into the system habitually in small amounts, and that it should be excluded from all articles of food intended for man.

On account of the growing tendency to mix other mill products of inferior value with wheat flour, such, for instance, as rye and corn flour, a law was passed by Congress in June, 1898, to meet the evil, and incidentally to make it a source of revenue. All adulterated flour is, by the act referred to, designated as "mixed flour," which term "shall be understood to mean the food product made from wheat mixed or blended in whole or in part with any other grain or other material, or the manufactured product of any other grain or other material than wheat." Under the provisions of the law, all persons engaged in the business of making mixed flour are required to pay a special annual tax, every package must be labelled plainly, the names of the ingredients being set forth, and upon every package of 196 pounds a tax of 4 cents shall be paid. Under the regulations of the Treasury, the term "mixed flour" is held not to include "the milling product from corn, rye, buckwheat, rice, or other cereals than wheat put upon the market as the flour or meal derived from such cereals, although the product may contain a percentage of wheat flour."

The detection of other cereals and starches in wheat flour is accomplished best by means of the microscope, since, as will appear, each has its characteristic appearance. According to Vogel, 70 per cent. alcohol containing 5 per cent. of hydrochloric acid remains colorless after being used to extract pure wheat or rye, turns pale yellow

if barley or oats be present, and orange-yellow if mixed with pea flour.

Rye.

In external appearance, rye presents a close resemblance to wheat, but the kernels are darker in color and smaller in size. It is by no means so important as wheat as an article of food in this country, but in some parts of Europe it constitutes the main food supply of the peasantry.

According to Wiley, a typical American rye should have approximately the following composition:

Moisture	10.50
Proteids	12.25
Ether extract	1.50
Crude fiber	2.10
Starch, etc.	71.75
Ash	1.90
	100.00

American rye is smaller than that grown abroad, and contains less moisture. The proteids of rye are more like those of wheat than those of any other cereal, and in consequence rye stands next to wheat in adaptability for bread-making. The yield of gluten is inferior in amount to that obtainable from wheat.

The starch of rye is much like that of wheat. The granules are rather more variable in size, the smallest of each kind being about equal, but the largest of rye somewhat surpassing those of wheat. There is but one point of difference in microscopic appearance which has any value in detecting the admixture of rye with wheat, namely, that a certain fair proportion of the larger sized granules of rye present irregular crosses or fractures. This is illustrated in Plate VII., Fig. 2.

Bread made from rye flour is but little inferior in nutritive value to that from wheat, but it is less pleasing to the eye, being of a brownish tint, and it has a peculiar sour taste, not altogether agreeable on first acquaintance. Not uncommonly, its use by one not habituated to it causes a tendency to diarrhœa, which, however, is soon overcome.

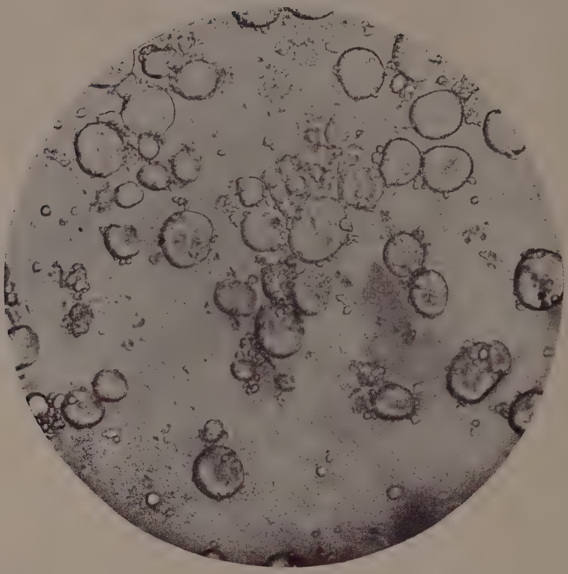
Barley.

This important cereal is used mainly in the manufacture of beer, and but to a limited extent as a food. Deprived of its husk and rounded and polished by attrition, it is known as "pearl barley," and in this form is used more or less in the preparation of barley-water, a drink for invalids. In its composition, barley is very similar to wheat and rye, but as its proteids yield no gluten, it cannot be made into bread. It is mixed sometimes with wheat flour for purposes of bread-making, but the product is less palatable and less digestible than ordinary bread.

Wiley gives the following as the approximate composition of a typical American unhulled barley:

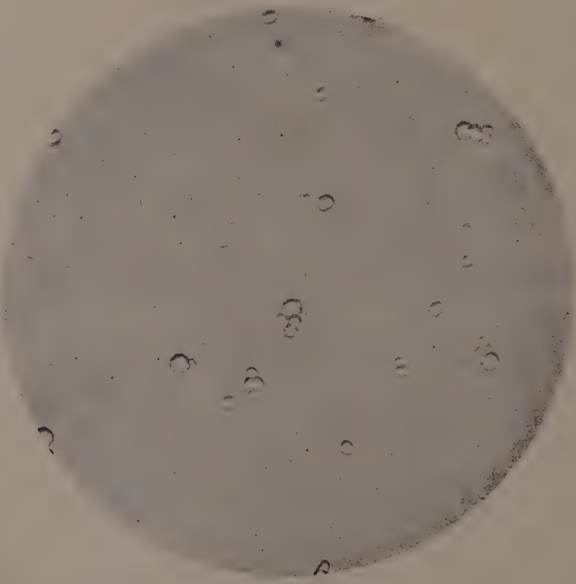
PLATE VIII.

FIG. 1.



Barley Starch. × 285.

FIG. 2.



Oats Starch. × 285.

Moisture	10.85
Proteids	11.00
Ether extract	2.25
Crude fiber	3.85
Starch, etc.	69.55
Ash	2.50
	100.00

The proteids include, as in all cereals, a number of complex substances, chief of which is hordein. The starch granules are like those of wheat, but are less variable in size. (See Plate VIII., Fig. 1.) In the manufacture of malt from barley for brewing, a peculiar nitrogenous product, diastase, is formed, which has the property of converting starch to sugar.

Oats.

Oats are much used as human food in the form of oatmeal, which is the product of grinding the kiln-dried seeds deprived of the husk. The meal has a peculiar taste, which is both sweet and bitter.

The composition of unhulled American oats, as given by Wiley, is as follows:

Moisture	10.00
Proteids	12.00
Ether extract	4.50
Crude fiber	12.00
Starch, etc.	58.00
Ash	3.50
	100.00

The mean composition of oatmeal, according to Blyth,[1] is as follows:

Moisture	12.92
Proteids	11.73
Fat	6.04
Sugar	2.22
Dextrin and gum	2.04
Starch	51.17
Fiber	10.83
Ash	3.05
	100.00

The proteids of oats yield no gluten, and hence this article of diet cannot be made into bread, though with water it can be made into thin cakes, which are most palatable. Fat is present is greater abundance than in any other cereal. The starch granules are very small polyhedra which show neither hilum nor concentric rings. They tend to adhere together in masses of variable size, which are disintegrated easily by trituration in a mortar. The single granules are shown in Plate VIII., Fig. 2.

Oatmeal is a very nutritious article of diet, used largely as a breakfast food in the form of porridge. It has a somewhat laxative action, and, therefore, should not be eaten in irritable conditions of the bowel. It is also likely to disagree with some dyspeptics, because of its tendency to cause acidity and heartburn.

[1] Foods: Their Composition and Analysis, London, 1896, p. 210.

Corn.

In the American usage of the word, corn includes the several varieties of Indian corn or maize. In England, the term is applied generally to wheat, rye, oats, and barley, and more specifically to wheat; in Scotland, it commonly means oats. In the United States, corn is in many ways the most important of the cereals, constituting in some parts of the country the chief bread food, and being the main source of starch and glucose.

The chief varieties are dent corn, showing a depression in the outer end of the kernel; flint corn, having a hard smooth exterior; sweet corn, rich in sugar and shrivelling when ripe; and pop-corn, a very flinty variety with small kernels, which contain a considerable amount of oil, which, in the process of roasting, explodes and causes the extrusion of the starchy interior in the form so universally familiar. The variety in most common use, from which the several kinds of meal, hominy, and samp are derived, is the flint corn. Hominy is the product obtained by grinding coarsely the kernels deprived of the hull by soaking. Samp is the whole, or practically the whole, of the kernel minus the germ and hull. Indian meal, or corn meal, is the product obtained by grinding the kernels between stones or by other processes of milling, and removing more or less of the bran by sifting or bolting. According to the process employed, we have coarse and fine, and white and yellow meal. Prepared without removal of the germ, which is rich in oil, the product is prone to become rancid and mouldy on keeping.

From a large number of analyses, Wiley deduces the following as the approximate composition of typical Indian corn:

Moisture	10.75
Proteids	10.00
Ether extract	4.25
Crude fiber	1.75
Starch, etc	71.75
Ash	1.50
	100.00

The average of 19 analyses of samples of sweet corn by Clifford Richardson, quoted by Wiley, shows:

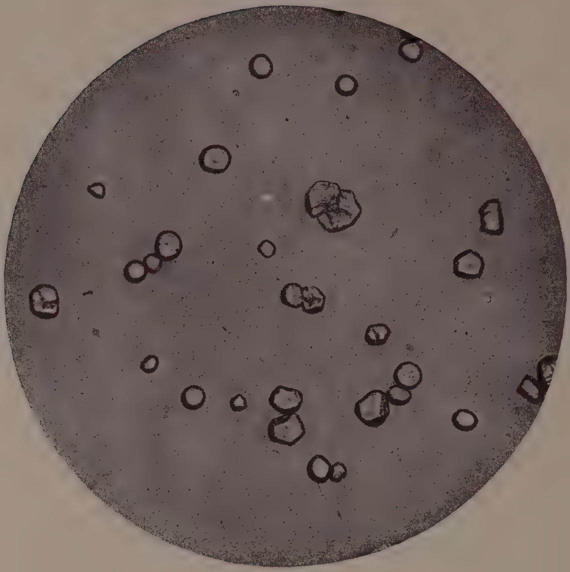
Moisture	8.44
Proteids	11.48
Ether extract	8.57
Crude fiber	2.82
Starch, etc	66.72
Ash	1.97
	100.00

The composition of fine meal is given by Wiley as follows:

Moisture	12.57
Proteids	7.13
Ether extract	1.33
Total carbohydrates	78.36
Ash	0.61
	100.00

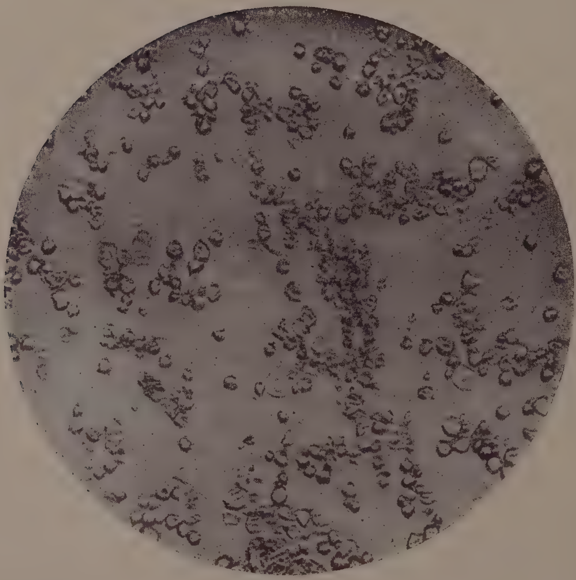
PLATE IX.

FIG. 1.



Corn Starch. × 285.

FIG. 2.



Rice Starch. × 285.

The lowered percentages of proteids and fats here shown are due to the removal of the germ, rich in fat, and of the finer envelopes, rich in proteids.

The proteids of corn, as determined by Chittenden and Osborne, are made up of several globulins, including myosine and vitelline, two classes of albumins, and two of zeins. The starch granules are polyhedral with rounded angles, and have a punctiform, sometimes stellated, hilum. They are much larger than those of oats, which they resemble somewhat in form. They are shown in Plate IX., Fig. 1.

On account of its deficiency in gluten, corn meal is not well adapted to the making of leavened bread, but it is used in many forms of substitutes therefor. It is mixed with salt and water, sometimes with the addition of milk or eggs, and baked into not over-thick cakes, which, according to the method of preparation and baking, are known as johnnycake, corn dodger, corn pone, and corn bread. Sometimes, yeast and baking powder are employed. Corn meal is used extensively in the form of hasty pudding, or corn mush, and of Indian pudding. In whatever form used, corn meal is a most nutritious and wholesome food.

Rice.

Rice is the principal food of a very large part, estimated at about a third, of the human race. Being, as will be seen, too poor in proteids, fat, and mineral matter to satisfy alone the needs of the body, the deficiencies are met by other vegetable products, as beans and peas, which are rich in these constituents.

The form in which rice is seen in the household is the result of a polishing process which removes the reddish cuticle which the grain shows on removal of the husk. Wiley's figures, representing the composition of typical polished rice, are as follows:

Moisture	12.40
Proteids	7.50
Ether extract	0.40
Crude fiber	0.40
Starch, etc.	78.80
Ash	0.50
	100.00

Rice is the richest of the cereals in starch, and the poorest in all other respects. The proteids have not yet been studied systematically. Its starch is very easily digestible, and is very useful in all disordered conditions of the digestive tract when other solid foods cannot be borne. Under the microscope, the starch granules are seen to be much like those of corn, but are much smaller and have sharper angles. They are separated less easily from one another, and are commonly in groups of variable size. They are shown in Plate IX., Fig. 2.

Rice cannot be made into bread, but sometimes is mixed with wheat flour, in order to give whiteness to the bread. It is used most commonly in the freshly boiled condition or in the form of puddings. The

most approved method of cooking it is steaming. This has the advantage of not taking away any of the already deficient proteids and salts, which to some extent are extracted in boiling, and also that it leaves the kernels distinct in themselves, and not aggregated in the form of a soggy mush, such as is produced often by improper boiling.

Buckwheat.

This valuable cereal is used very extensively in this country as a breakfast food in the form of pancakes eaten hot with syrup or with butter and sugar. As it is devoid of gluten, it cannot be made into bread.

The composition of typical American buckwheat is given as follows:

Moisture	12.00
Proteids	10.75
Ether extract	2.00
Crude fiber	10.75
Starch, etc.	62.75
Ash	1.75
	100.00

The crude fiber is removed very largely in the milling, and is almost wholly absent from the white flour, a sample of which, analyzed by Wiley, had the following composition:

Moisture	11.89
Proteids	8.75
Ether extract	1.58
Crude fiber	0.52
Starch, etc.	75.41
Ash	1.85
	100.00

Buckwheat is the most expensive of the cereals, and consequently is the most subject to adulteration with the cheaper members of the class. The admixture is detected readily by the microscope, since the starch granules have a very characteristic appearance, being small and angular, and of nearly uniform size. Ordinarily they are seen in fairly large masses which are not disintegrated in the process of milling. The starch is shown in Plate X., Fig. 1.

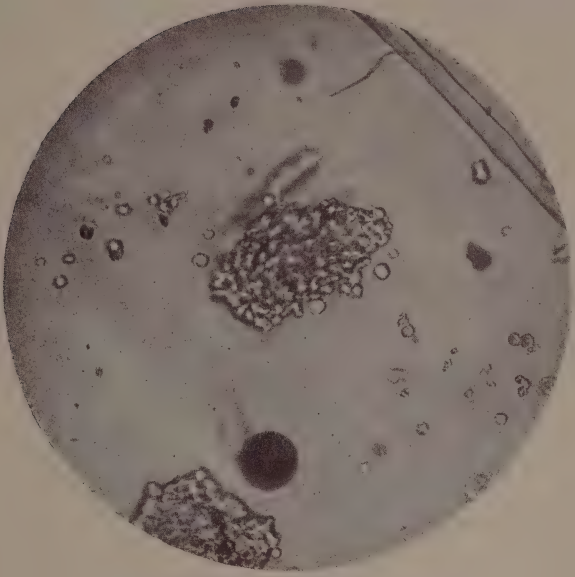
(*b*) LEGUMES.

This group comprises peas, beans, and lentils. It is characterized by richness in proteids, which may be present in more than double the amount found in wheat. The chief proteid is legumin, which much resembles casein, and is known commonly as vegetable casein. According to E. Fleurent,[1] the proteids of this group consist of vegetable casein, composed of legumin and glutenin, and vegetable fibrin, composed of albumin and gliadin. Thus:

[1] Comptes rendus, 1898.

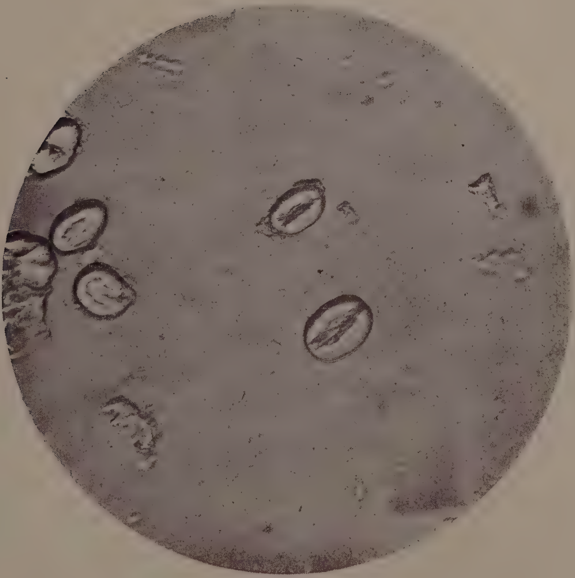
PLATE X.

FIG. 1.



Buckwheat Starch. × 285.

FIG. 2.



Pea Starch. × 285.

Vegetable casein	legumin	60.95
	glutenin	30.65
Vegetable fibrin	albumin	0.64
	gliadin	7.76
		100.00

Their high content of proteids makes them more satisfying than other vegetable foods, and enables them to act as a fair substitute for animal food. The millions of rice-eaters who, by reason of poverty or religious scruples, are denied the use of animal food, depend upon the legumes to supply the demands of the body for nitrogen. The East Indian, for instance, has no difficulty in satisfying his bodily needs with a handful of beans added to his daily ration of rice. While legumes possess a very high nutritive value, they must be ranked as much more difficult of digestion than the cereals. They require prolonged boiling when cooked whole, but are prepared more quickly and digested more completely when ground into meal and cooked with milk. Even under the most favorable conditions, a large part of the proteids is lost in the excreta. Rubner has shown that a fifth to a third is not digested and absorbed, whereas in the case of bread the proteid loss is less than a seventh.

Some individuals are obliged to forego the use of peas and beans, on account of flatulence due to the formation of sulphuretted hydrogen from the sulphur in the legumin. This objection does not apply to lentils, since they contain no sulphur.

Peas.

The average of 61 analyses of peas, compiled by König, is as follows:

Moisture	14.99
Proteids	22.85
Fat	1.79
Crude fiber	5.43
Starch, etc	52.36
Ash	2.58
	100.00

When dried peas become old, no amount of boiling will make them soft, and they should then be soaked and crushed and cooked in some other way. The immature pea, so highly prized as a spring and summer vegetable, has a very different composition. Five analyses, compiled by Atwater and Bryant,[1] yielded the following average results:

Moisture	74.6
Proteids	7.0
Fat	0.5
Carbohydrates, including fiber	16.9
Ash	1.0
	100.0

[1] Loco citato.

The canned pea appears to contain considerably less nutriment. Of 88 samples reported by the same authorities, none contained less than 77.5 per cent. of water, and some contained as much as 92.7. Their average composition was as follows :

Moisture	85.3
Proteids	3.6
Fat	0.2
Carbohydrates	9.8
Ash	1.1
	100.0

The starch granules of peas are represented in Plate X., Fig. 2.

Beans.

There are many varieties of beans belonging to the two large groups, the broad beans and the kidney beans, but their composition is in general quite similar. Forty-one analyses of broad beans and 10 of kidney beans compiled by König give the following averages :

	Broad.	Kidney.
Moisture	14.76	13.74
Proteids	24.27	23.21
Fat	1.61	2.14
Crude fiber	7.09	3.69
Starch, etc	49.01	53.67
Ash	3.26	3.55
	100.00	100.00

Eleven analyses compiled from American sources by Atwater and Bryant yield averages not materially different.

Five analyses of string beans in the fresh state and 29 of canned samples yield the following averages, showing, as in the case of peas, that the canned variety is less nutritious :

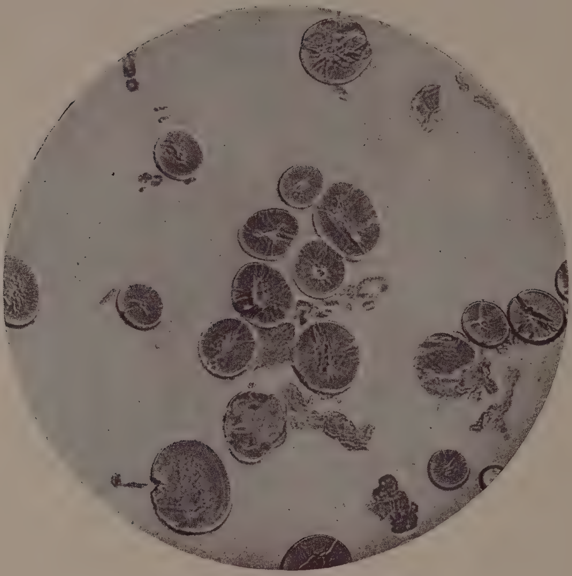
	Fresh.	Canned.
Moisture	89.2	93.7
Proteids	2.3	1.1
Fat	0.3	0.1
Total carbohydrates	7.4	3.8
Ash	0.8	1.3
	100.0	100.0

The Soja bean, which has been recommended highly in some quarters as a suitable food for diabetics, is remarkable for its high content of fat, and contains, in addition, so large an amount of starch as to make it quite unsuited to the dietary of the diabetic. König has compiled 21 analyses from all sources, and Jenkins and Winton [1] have collected 10 more from American sources. The two groups give the following averages :

[1] Experiment Station Bulletin, No. 11, Washington, 1892.

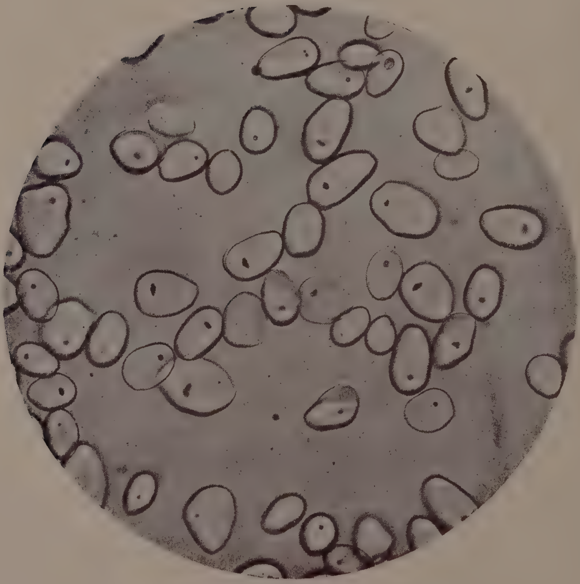
PLATE XI.

FIG. 1.



Bean Starch. × 285.

FIG. 2.



Arrowroot Starch. × 285.

	König.	Jenkins and Winton.
Moisture	9.51	10.80
Proteids	33.41	33.98
Fat	17.19	16.85
Crude fiber	4.71	4.79
Starch, etc	29.99	28.89
Ash	5.19	4.69
	100.00	100.00

Bean starch is shown in Plate XI., Fig. 1.

Lentils.

Lentils are the most nutritious of the legumes, but are not a popular food in this country, excepting among certain of the foreign-born population. Their use is, however, on the increase. The averages of 14 analyses compiled by König are as follows:

Moisture	12.34
Proteids	25.70
Fat	1.89
Crude fiber	3.57
Starch, etc	53.46
Ash	3.04
	100.00

2. Farinaceous Preparations.

Under this head are included sago, tapioca, and arrowroot.

SAGO.

Sago is derived from the pith of the stems of a number of species of palms. The pith is extracted and ground to a powder, which then is mixed with water and strained. The starch granules pass through with the water, and are deposited as a sediment, which constitutes the sago flour. From the flour, made into a paste, the various forms of granulated sago are prepared.

Sago is an important starch preparation, and serves as a light and digestible food for invalids and dyspeptics, but its use is not restricted to these alone. It absorbs the liquid in which it is cooked, and becomes soft and transparent, but retains its original form.

TAPIOCA.

Tapioca is derived from a thick fleshy tuberous root called "manihot." The starch, which is extracted by a method similar to that employed in the preparation of sago, is heated in a moist state on hot plates and stirred with iron rods, and thus forms irregular masses of transparent granules. In the process of heating, many of the starch granules become ruptured, and are then partially soluble in cold water. Tapioca, like sago, is useful for both sick and well.

ARROWROOT.

Arrowroot is a pure form of starch from the tuberous root of the maranta. Its name is derived from the fact that the maranta root is believed to counteract the effects of arrow poison. It is used chiefly as a bland article of food in the sick-room in the form of light pudding or other desserts, but may be combined with other starch foods and made into bread. There are several varieties, the best of which come from Bermuda and Jamaica. Corn starch is employed frequently as a fair substitute. Arrowroot starch is shown in Plate XI., Fig. 2.

3. Fatty Seeds (Nuts).

Nuts are rich in fat and proteids, but contain no starch. They are of high nutritive value, but on account of their richness in fat they are not easily digested, even when reduced to a finely divided state.

ALMONDS.

In the countries where they are produced, the almond is eaten both in the green and dry conditions. The ripe kernel has a skin, with a bitter disagreeable taste. When this is removed by soaking for a time in warm water, the almond is known as "blanched."

There are two varieties of almond, the sweet and the bitter, both of which contain more than 50 per cent. of oil, about half as much proteid material, gum, sugar, and crude fiber. Both contain emulsin, a substance which, in the presence of water, acts upon the glucoside amygdalin, present only in the bitter variety, to form hydrocyanic acid, glucose, and benzoic aldehyde. On account of this reaction, the bitter almond is not always safe, and fatal results have occurred from its ingestion.

When almonds are baked, they are made more brittle, and are reduced more easily to a powder.

COCOANUTS.

The fleshy white kernel of the cocoanut contains about 70 per cent. of fat. The milky interior is chiefly water, but contains nearly 7 per cent. of sugar.

WALNUTS.

All of the trees of the genus *Juglans* yield nuts classed as walnuts. The different varieties, though varying in outward appearance and in taste, have practically the same composition. They contain about 60 per cent. of fat, about 16 per cent. of proteids, and about 7 per cent. of sugar and gum. The hazel nut, which belongs to the oak family has about the same composition.

PEANUTS.

The peanut, known also as ground nut and goober, is less rich in fat, but richer in proteids than other nuts. It contains about 45 per cent. of the former and about 30 per cent. of the latter.

CHESTNUTS.

The chestnut is not of this class, but for convenience will be considered here rather than with the farinaceous seeds, in which class it properly belongs. It contains but little fat and proteids, about 15 per cent. of sugar, about 25 per cent. of starch, and about 50 per cent. of moisture. It is very indigestible in the raw state, and even when cooked is very trying to the digestion of those with weak stomachs. It is used very extensively as a food by the French, Spanish, and Italian peasantry in various cooked forms, and largely in the form of bread.

4. Vegetable Fats.

The vegetable fats include the oils derived from the olive, cotton-seed, peanut, and other seeds. They are used in the preparation of salads and for frying. The most important are the two first mentioned.

OLIVE OIL.

Olive oil is a bland fixed oil derived from the fruit of the many varieties of the olive tree. It is known by various names which designate the grade, but is sold for the most part as virgin oil, which is the choicest grade of all and not extensively marketed. Virgin oil is made from the choicest olives, about three-fourths ripe, which are bruised only slightly in the mill, so that only the olive pulp, and not the stone, is crushed. The crushed mass is gathered in a heap, and the oil is allowed to drain away without pressure or other influence of any kind. The product has a greenish tint and a far more delicate taste than that made in the manner to be described.

In the manufacture of the grades ordinarily seen in the market, the olives, both pulp and stones, are ground into an oily paste, which is packed into bags made of woven grass. These are placed in piles and subjected to pressure. As the oil drains away, boiling water is applied to the bags to keep up the flow, and that which is thus obtained constitutes the lower grade. Sometimes, the pressed pulp is thrown into water and separated from the broken kernels, which sink to the bottom. The pulp is then gathered up and pressed again.

On account of the cost of pure olive oil, adulteration with other cheaper oils is practised very extensively. The principal adulterant is cotton-seed oil, which is exported from this country in large quantities for this and other purposes. Much of the oil sold in this country as olive oil is cotton-seed oil put up in the cheapest kinds of bottles, adorned with gaudy labels bearing inscriptions often not remarkable for accuracy in the use of the French language. The author has seen, for

example, labels which indicated that the contents of the bottles had been "virginated."

Adulteration of olive oil to only a slight extent with the cheaper oils is by no means easy of detection, but when the fraud is fairly extensive it may be shown by chemical tests and by the use of the refractometer, the refractive index of olive oil being less than that of the cheaper substitutes. The iodine number and saponification equivalent of olive oil are both less than those of its adulterants. The behavior of olive oil in contact with nitric acid or with alcoholic solution of nitrate of silver is markedly different from that of the cheaper oils. Thus, equal volumes of strong nitric acid and olive oil, mixed together and agitated in a flask, give a product which has either a greenish tinge or at most one inclining to orange, and no marked change is perceptible on standing for five or ten minutes; whereas cotton-seed oil similarly treated yields almost immediately a reddish color, which shortly darkens and becomes dark brown or almost black.

Again, if 12 cc. of a suspected sample are mixed in a test tube with 5 cc. of a 2.5 per cent. solution of nitrate of silver in 95 per cent. alcohol, and placed in a beaker of boiling water, the resulting change of color gives indications as follows: if olive oil, the color is greenish; if cotton-seed oil, it becomes black; if sesame oil, it is dark reddish-brown; if peanut oil, it is at first reddish brown, then greenish and turbid; if poppy oil, it is greenish yellow. For further details of chemical tests, the reader is referred to the standard works on the adulteration of foods.

COTTON-SEED OIL.

This very important and cheap vegetable fat is a perfectly wholesome and desirable article of food. It is much used under its own name as a substitute for lard and olive oil for frying, and in place of the latter as an ingredient of dressings for salads. It lacks the fine flavor of olive oil, but its substitution in dressings can be detected only by the educated palate. From a hygienic standpoint, there is absolutely no objection to its use in the preparation of foods. The same may be said of the other cheap vegetable oils.

5. Tubers and Roots.

In the cooking of tubers, roots, and other vegetables, the albumins and globulins are coagulated, the fibrous matters in the cell walls are softened and ruptured, the starch granules swell and burst, the starch itself becomes somewhat changed in character, and the whole mass is made more digestible. When boiling is the process employed, part of the mineral matter and more or less of the other soluble substances, including certain proteid material, are extracted and lost.

POTATOES.

The potato is the most important member of this group. It was introduced into Spain from Peru about the middle of the sixteenth century,

PLATE XII.

Potato Starch. × 285.

and later, in 1585, into Ireland from Virginia, by Sir Walter Raleigh, who, in the following year, introduced it also into England. Prior to that time, and even later, what was known in England as the potato and the "common potato" mentioned by Gerard in his Herbal (1597), were sweet potatoes, "batata," introduced from Spain.

The averages of 136 analyses (American samples) compiled by Atwater and Bryant are as follows:

Moisture	78.3
Proteids	2.2
Fat	0.1
Total carbohydrates	18.4
Ash	1.0
	100.0

These figures differ but slightly from the averages of 178 analyses of European samples.

The proteids of the potato are chiefly in the albuminous juice between and in the cells. Most of the mineral matter is salts of potassium, and this, too, is almost wholly in the juice. The starch was discovered by Lenbert and Georgiewsky to be acted upon much more readily by the salivary enzyme than any of the cereal starches. The starch granules are much larger and more irregular in shape than any of those thus far shown. The hilum and concentric rings are quite distinct. (See Plate XII.)

In the process of cooking, the albuminous juice is coagulated and its watery part is absorbed by the starch granules, which swell and consequently distend the cells in which they are lodged. The coherence of the cells is reduced, and then they are separated easily into a mealy mass. If the watery part of the juice is not wholly absorbed, the cells are separated with more or less difficulty, the potato remains firm instead of becoming mealy. and is then spoken of as close, waxy, or watery. In this state it is digested much less easily, and may, indeed, be very trying to the stomach. The same condition is noticed in the case of potatoes which have been frozen; they are very watery and of inferior flavor however they are cooked.

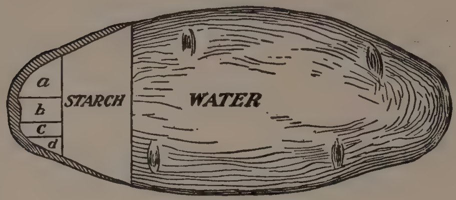
According to Balland,[1] the mealy condition is due not, as supposed, to an especially high content of starch, but to a low percentage of albumin, for a potato rich in this substance keeps its shape and neither cracks nor falls apart. He also points out that beneath the skin there are three well-defined layers, which may readily be seen by holding a thin cross-section against a strong light. The outermost is richest in starch and poorest in proteids, but in the innermost these conditions are reversed; the middle layer represents the mean composition of the whole.

The loss which occurs on boiling is much less when the skins are left intact than when removed; the greatest loss occurs when the potatoes are peeled first and then soaked in cold water. When cooked by steaming, there is no loss whatever. The material lost in boiling

[1] Journal de Pharmacie et de Chemie, 1897, VI.

has been determined by H. Snyder[1] as follows: Skins removed, soaked 3 hours: total nitrogen, 46 per cent.; ash, 45.6 per cent. Skins removed, not soaked: total nitrogen, 16.9 per cent.; ash, 17.9 per cent. Skins not removed: total nitrogen, 1 per cent.; ash, 3.4 per cent.

Fig. 5.



a, fiber, pectose, fat, etc.; *b*, non-albuminoid nitrogenous matter; *c*, albuminoid nitrogenous matter; *d*, mineral matter. The hatched portion represents the loss. (After Snyder.)

The composition of the potato and the loss of nutrients when boiled with the skin removed are shown by Snyder by a drawing, which is here reproduced. (See Fig. 5.)

Potatoes are so deficient in nitrogen that alone they do not constitute a proper ration, but with foods rich in proteids, such as meats, beans, or peas, they are valuable and economical.

The juice of the potato contains citric acid and citrates of potassium, sodium, and calcium, which fact accounts for the antiscorbutic value of this vegetable.

Attention has often been called to the fact that the potato belongs to a poisonous botanical family, which includes belladonna, stramonium, hyoscyamus, and tobacco, all powerful narcotic plants; and it has been pointed out as a paradox that this valuable food possesses no poisonous properties. This, however, is not true, for the potato has been the frequent cause of more or less extensive outbreaks of poisoning, and it has long been known that the normal potato contains about .006 per cent. of solanin, and that, when sprouting, the solanin content is materially increased. Between 1892 and 1898, many outbreaks of poisoning occurred in the 15th (German) Army Corps, which were traced by Schmiedeberg and Meyer[2] to solanin in sprouting or completely ripe potatoes. Schmiedeberg's assertion that solanin formation in potatoes is caused by bacteria has been proved by R. Weil,[3] who demonstrated that at least two organisms, *Bacterium solaniferum non-colorabile* and *Bacterium solaniferum colorabile*, have the property of producing solanin from substances normally present.

A noteworthy instance of potato-poisoning is that recorded by Pfuhl.[4] Fifty-six soldiers of a company of the German Army were seized with symptoms of acute gastro-enteritis. The sickness began with chills, fever, headache, colic, vomiting, and diarrhœa. In a number of cases there was collapse, with more or less jaundice. None of the cases ended fatally, nor were there any relapses or sequelæ. Investigation showed that the men had eaten sprouting potatoes, a sample of which yielded .038 per cent. of solanin, and that, therefore, those who had eaten their

[1] Department of Agriculture, Office of Experiment Stations, Bulletin No. 43, 1897.
[2] Archiv für experimentelle Pathologie und Pharmakologie, 1895.
[3] Archiv für Hygiene, XXXVIII. (1900), p. 330.
[4] Deutsche medicinische Wochenschrift, 1899, p. 753.

full portion of the vegetable had ingested about 0.3 gram of the poison, a quantity which may easily induce serious symptoms.

SWEET POTATOES.

The average composition of sweet potatoes (95 analyses) is given by Atwater and Bryant as follows:

Moisture	69.0
Proteids	1.8
Fat	0.7
Total carbohydrates	27.4
Ash	1.1
	100.0

Starch constitutes much the greater part of the carbohydrates; the remainder is mainly sugar.

ARTICHOKES.

The Jerusalem artichoke is so named, not after the city of Jerusalem, but from a corruption of the Italian word *girasole*, meaning sunflower, to which family the plant belongs. This tuber is quite sweet to the taste, but it is not so agreeable as the potato. It contains no starch, but yields about 15 per cent. of sugar. It is about twice as rich in proteids as the potato. When cooked, it becomes soft and watery.

FIG. 6.

a, fiber, starch, fat, etc.; *b*, sugar; *c*, non-albuminoid nitrogenous matter; *d*, albuminoid nitrogenous matter; *e*, mineral matter. The hatched portion represents the loss when medium-sized pieces were boiled. (After SNYDER.)

ROOTS.

The carrot, beet, parsnip, turnip, oyster plant, and radish agree in a general way in composition, and may be considered together. They are very poor in proteids, and contain but a small amount of other nutrients. All of them are valuable on account of their antiscorbutic properties, for providing variety in the diet, and for flavoring other foods. Their average composition, according to Atwater and Bryant, is set forth in the following table:

	No. of analyses.	Water.	Proteids.	Fat.	Carbohydrates including fiber.	Ash.
Beets	24	87.5	1.6	0.1	9.7	1.1
Carrots	18	88.2	1.1	0.4	9.3	1.0
Oyster plant [1]	1	80.4	1.0	0.5	17.1	1.0
Parsnips	3	83.0	1.6	0.5	13.5	1.4
Radishes	4	91.8	1.3	0.1	5.8	1.0
Turnips	19	89.6	1.3	0.2	8.1	0.8

Snyder represents diagrammatically the composition of the carrot and the loss of nutrients when boiled. (See Fig. 6.) On account of the general resemblance in composition, this diagram may be taken fairly to represent the whole group.

[1] The figures for oyster plant are taken from König.

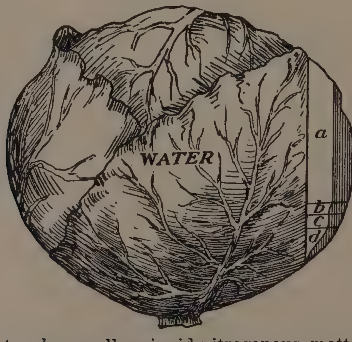
6. Herbaceous Articles.

These include various leaves, stems, and shoots. They contain but little nutriment, but are valuable for their salts, and for the variety which they give to the diet. It is to be noted, however, that in proteids they are, as a class, equal or superior to the tubers and roots. They contain unimportant amounts of fat and sugar. The *cabbage* and allied plants are not easily digested, and on account of containing more or less sulphur, may give rise to disagreeable flatulence, and are not suited to weak digestions. *Spinach* is regarded as slightly laxative. *Celery* is not easily digested in the raw state, but is easily borne when stewed. *Lettuce, cresses,* and similar articles for salads are wholesome and digestible. *Asparagus,* while containing but little nutriment, is prized particularly for its delicate flavor. *Onions* and *leeks,* being modified stems, belong in this group. They contain volatile oils which act as gentle stimulants.

The following table, compiled from Atwater and Bryant, gives the composition of the members of this group:

	No. of analyses	Water.	Proteids.	Fat.	Total carbo-hydrates.	Ash.
Asparagus	3	91.6	2.1	3.3	2.2	0.8
Cabbage	16	91.5	1.6	0.3	5.6	1.0
Cauliflower	2	92.3	1.8	0.5	4.7	0.7
Sprouts	1	88.2	4.7	1.1	4.3	1.7
Celery	5	94.5	1.1	0.1	3.3	1.0
Lettuce	8	94.7	1.2	0.3	2.9	0.9
Spinach	3	92.3	2.1	0.3	3.2	2.1
Beet tops	1	89.5	2.2	3.4	3.2	1.7
Dandelions	1	81.4	2.4	1.0	10.6	4.6
Leeks	1	91.8	1.2	0.5	5.8	0.7
Onions	15	87.6	1.6	0.3	9.9	0.6

Fig. 7.



a, starch, sugar, fiber, fat, etc.; *b*, non-albuminoid nitrogenous matter; *c*, albuminoid nitrogenous matter; *d*, mineral matter. The hatched portion represents the loss. (After Snyder.)

The composition of the cabbage and the loss incurred through boiling are shown in the accompanying figure (Fig. 7), by Snyder.

In a general way it may be accepted as representing the entire group.

7. Fruit Products Used as Vegetables.

These include the tomato, cucumber, squash, pumpkin, egg-plant, and vegetable marrow. The *tomato* is consumed largely in the raw state as a salad, and in several cooked forms. It contains less than 6 per cent. of solid matter, and in this respect has about the same nutritive value as celery and lettuce. Its chief solid matter is sugar. Its mineral constituents are free from earthy salts. The *cucumber* in the raw state, in which condition it is eaten most commonly, is not easy of digestion; but when stewed, is light, wholesome, and agreeable. As a nutriment it stands even lower than the preceding, containing less than 5 per cent. of solid matter. The *squash, pumpkin, vegetable marrow*, and *egg-plant* have about equal nutritive value. They contain about 90 per cent. of water, are very poor in proteids—less than 1 per cent.—but are fairly rich in carbohydrates.

8. Fruits.

As stated above, the word *fruits* is used here in its narrower sense to designate those products which, being of an agreeable taste in the raw state, are suitable for use as a dessert. The agreeable taste depends upon the relative proportions of pectin, sugar, gum, acids, and other constituents. Some fruits with but a small percentage of sugar and considerable acid have a sweeter taste than others richer in sugar and with no more acid, because of the masking of the free acid by the gum and pectin. Thus, the peach, for instance, is comparatively poor in sugar, but its content of acid is prevented from being prominent by the large content of gum and pectin. Some fruits contain usually but little of these constituents.

Fruits contain but little proteid matter, and their chief food value lies in the sugar, salts, and vegetable acids which they contain. Eaten in moderation, they exert a favorable influence on the system, but when taken in undue proportion to other foods, and especially in unripe or too ripe states, may cause digestive derangements. On account of their richness in vegetable acids and their salts, which in the system are decomposed and converted to carbonates, they tend to diminish the acidity of the urine.

APPLES.

In the raw state, apples are not very easy of digestion, but when cooked they are much more so, and when baked are reputed to be slightly laxative and, therefore, useful in habitual constipation, but not suitable in the reverse condition. From the many analyses which have been compiled by various authorities, it may be stated that this fruit contains about 85 per cent. of water, 7.5 per cent. of sugar, 1 of malic

acid, 0.4 of ash, besides variable amounts of pectin, pectose, fiber, and other matters.

PEARS.

Pears are somewhat richer than apples in sugar and poorer in malic acid. They are fairly rich in pectin.

PEACHES.

In this fruit, the sugar is comparatively low, but the pectous matter is exceptionally high and covers the acidity. Peaches contain nearly 1 per cent. of malic acid.

APRICOTS.

The sugar content of apricots is about equal to that of peaches. The pectous matter is also about the same in amount, but the acidity is higher.

PLUMS.

Plums contain, as a rule, less sugar and pectin and more malic acid than are found in peaches and apricots. They are much more likely than most other fruits to disagree and produce derangement of digestion.

CHERRIES.

Cherries are notable for their large content of sugar, over 10 per cent., surpassing in this respect all of the foregoing. They contain somewhat less than 1 per cent. of malic acid and are low in pectin. The popular idea that, even in ripe, sound condition, they are a dangerous article of food if eaten in conjunction with milk, has no foundation in fact; but when unripe or unsound, they have a tendency to cause disorder of the bowels.

The average composition of the foregoing fruits is shown in the following table, compiled from König:

	Water.	Sugar.	Acid.	Proteids.	Pectin, etc.	Fiber.	Ash.
Apples	83.79	7.22	0.82	0.36	5.81	1.51	0.49
Pears	83.03	8.26	0.20	0.36	3.54	4.30	0.31
Peaches	80.03	4.48	0.92	0.65	7.17	6.06	0.69
Apricots	81.22	4.69	1.16	0.49	6.35	5.27	0.82
Plums	84.86	3.56	1.50	0.40	4.68	4.34	0.66
Cherries	79.82	10.24	0.91	0.67	1.56	6.07	0.73

ORANGES.

The orange contains nearly 2.5 per cent. of citric acid and about 4.5 of sugar. The juice is particularly agreeable in almost any condition of health or sickness, and is extremely unlikely to cause any disturbance of the system.

The average composition of oranges (23 analyses), according to Atwater and Bryant, is as follows:

Water	86.9
Proteids	0.8
Fat	0.2
Total carbohydrates, including fiber	11.6
Ash	0.5
	100.0

GRAPES.

The juicy pulp of the grape is wholesome and refrigerant, and when eaten in large amounts exerts a gentle laxative action. Since the number of varieties reaches into the thousands, it follows that wide variation in composition must occur.

Twelve analyses compiled by König yield the following averages:

Water	78.17
Sugar	14.36
Free acid	0.79
Proteids	0.59
Pectous matter	1.96
Fiber	3.60
Ash	0.53
	100.00

Five analyses compiled by Atwater and Bryant yield averages which are expressed somewhat differently, as follows:

Water	77.4
Proteids	1.3
Fat	1.6
Total carbohydrates, including fiber	19.2
Ash	0.5
	100.0

When dried in the sun or in ovens, the product is *raisins*. Those dried in the sun are the better. Raisins are less digestible than grapes, and are not infrequently the cause of derangement of the intestinal canal.

What are known commonly as *dried currants* are raisins made from small seedless grapes. They come from the Levant, and are shipped from Corinth, whence their name in a corrupted form. They are exceedingly indigestible, and are likely to traverse the entire digestive tract without undergoing change.

MELONS.

The edible portion of melons is very watery, but the small amount of nutriment contained is not unlikely to cause in many persons digestive disturbances accompanied by annoying eructations. Not many analyses have been recorded. Storer,[1] quoted by König, has reported three analyses, which give the following averages:

[1] Report of Connecticut Experiment Station, 1879, p. 159.

Water	88.09
Proteids	0.92
Fat	0.18
Sugar, etc.	9.05
Fiber	1.04
Ash	0.72
	100.00

Two analyses of watermelons noted by Atwater and Bryant give the following averages:

Water	92.4
Proteids	0.4
Fat	0.2
Total carbohydrates, including fiber	6.7
Ash	0.3
	100.0

BANANAS.

Bananas and plantains are among the most nutritious of fruits; in many parts of the tropics, they constitute the chief food of those who are too lazy to perform any kind of manual labor. The edible part yields about 20 per cent. of sugar (cane and invert), about 2 of proteids, 0.5 of starch, and rather more of fat.

FIGS.

The fig in the fresh state is about equal to the banana in nutritive properties. In both the fresh and dried forms, it is esteemed highly as a mild laxative. The dried fig contains about 30 per cent. of water, 50 of sugar, 4 of proteids, and 3 of ash; the remainder is chiefly seeds and fiber.

BERRIES.

The various berries are notable for their content of free acids and sugar. Two kinds, the cranberry and the barberry, are too sour to be eaten raw, and must be cooked with sugar in order to be made palatable. The composition of the several members of this group is set forth in the following table, compiled from König:

	Water.	Sugar.	Free acid.	Proteids.	Fiber, pectin, etc.	Ash.
Blackberries	86.41	4.44	1.19	0.51	6.97	0.48
Cranberries	89.59	1.53	2.34	0.12	6.27	0.15
Currants	84.77	6.38	2.15	0.51	5.47	0.72
Gooseberries	85.74	7.03	1.42	0.47	4.92	0.42
Huckleberries	78.36	5.02	1.66	0.78	13.16	1.02
Mulberries	84.71	9.19	1.86	0.36	3.22	0.66
Raspberries	85.74	3.86	1.42	0.40	8.10	0.48
Strawberries	87.66	6.28	0.93	1.07	3.25	0.81

9. Edible Fungi.

MUSHROOMS.

Mushrooms are reputed to be extremely rich in nitrogen and other nutrients, and accordingly they are recommended as a valuable food material. It is true that they are somewhat rich in nitrogen, but it should be said that a large proportion of this element present is in combinations (amido compounds) which are useless as food. As a matter of fact, the total solid matter of mushrooms averages about 12 per cent., and is largely woody matter. Mushrooms are rather difficult of digestion, and are not at all adapted to weak stomachs. They have been called "the poor man's meat," and much has been done to encourage the poor to seek for them in the fields and woods, in order to add to the larder. Inasmuch as the market price of mushrooms for the tables of the rich is generally high, and since their food value is decidedly overrated, it would appear that, where there is a market for them, the poor can do much better for their nutrition by disposing of their findings and converting the proceeds into cheaper, more digestible, more nutritious, and less cloying articles of food.

Truffles contain more nitrogen than is found in mushrooms, but they are very much more woody, and can hardly be looked upon as valuable from the point of view of nutrition.

10. Saccharine Preparations.

Sugar was known to the ancient Greeks and Romans, and its manufacture has been conducted by the Chinese since the earliest times. It is very soluble and diffusible, and, therefore, is digested easily. Dextrose is ready for assimilation, but sucrose, maltose, and lactose must undergo first a splitting process within the digestive tract.

CANE SUGAR.

Cane sugar is obtained from the sugar cane, sugar beet, sorghum, and sugar maple. It is very soluble in water, but quite insoluble in absolute alcohol. Heated with dilute mineral acids or with citric acid, it splits into dextrose and lævulose, and then is known as invert sugar from the fact that the polarization becomes inverted. Cane sugar rotates the plane of polarized light to the right; the two substances into which it is split, dextrose and lævulose, rotate respectively to the right and left, but the action of lævulose is so much the stronger that the mixture gives left polarization.

Heated above 180° C., sugar yields caramel, which is not a simple substance, but a complex mixture of brown products of dehydration. It is used as a coloring for low-grade milk and other articles of food, and somewhat as a flavoring.

Cane sugar is sold in various forms: cut or loaf sugar, granulated, and powdered. The cheaper grades, known from their color as "brown

sugars," contain variable amounts of invert sugar, gummy matters, and other impurities.

Sugar is not much subject to adulteration, though there is a popular idea that glucose and sand are common admixtures. It is probable that sand is as rare an adulterant of sugar as chalk is of milk. Glucose rarely is mixed with sugar, but is used considerably as a substitute for it in the manufacture of cheap jellies, jams, and candies. Sugars that are somewhat "off color" are treated sometimes with ultramarine in the final processes of manufacture. This corrects the fault and makes the product white. Occasionally, the amount added is sufficient to cause great alarm in the household when large quantities of sugar are made into syrup with hot water in the preparation of preserves and jellies. The blue material comes to the surface as a scum, and its unlooked-for appearance gives rise to suspicion of poison.

MAPLE SUGAR.

This form of cane sugar is prized highly for its agreeable flavor. It is a much more expensive article than ordinary sugar and is used more as a confection. In the form of syrup, it is used very extensively on buckwheat cakes and with other cereal breakfast foods. It is much subject to adulteration and substitution. A large part of the syrup in the market is wholly artificial, being made of ordinary sugar or glucose, appropriately colored, and correctly flavored by means of extract of hickory bark. The sugar itself is imitated in the same way, but one not infrequently sees specimens which are absolutely devoid of any flavor save that of brown sugar. The substitution by flavored cane sugar is easily proved by determining the amount of precipitate of lead malate yielded by 5 grammes of the suspected sample in 10 c.c. of water on the addition of basic lead acetate solution. Five grammes of pure maple sugar so treated should yield, after centrifugation, 2.5 c.c. of precipitate, while pure cane sugar yields none. The presence of glucose is revealed by the behavior of the specimen under polariscopic analysis.

GLUCOSE. DEXTROSE.

Dextrose, or grape sugar, is inferior in sweetening power to cane sugar, and is not crystallizable to the same extent. It is much less soluble in water, but is soluble in glycerin and in alcohol of ordinary strength. It is found in grapes and in many other fruits and vegetables, but always associated with lævulose. By fermentation with yeast, it splits into carbonic acid and alcohol; in the presence of ferments which disorganize proteids, it yields lactic acid. It exerts a strong reducing power on Fehling's solution.

Commercial glucose is obtained by heating starch, usually corn starch, with diastase or dilute sulphuric acid. Before the final process of concentration of the solution, the acid is neutralized completely by the application of marble dust, and the resulting sulphate of calcium

and the excess of the neutralizing agent are removed. The product always contains considerable proportions of maltose and dextrin, and its rotatory power is, therefore, much greater than that of pure glucose, such as is obtainable from diabetic urine.

Glucose is produced in enormous quantities both in the solid form and as a thick colorless syrup. It is used in the manufacture of cheap candies, jams, and preserves, in the brewing of beer, and as an adulterant of molasses and honey (see under Beer).

MOLASSES.

Molasses is a thick, viscid, dark-colored liquid, which drains away in the process of the manufacture of sugar. It contains from 65 to 72 per cent. of sugar, part of which is sucrose and part fruit sugar, various salts, gummy matters, extractives, and water. It is graded according to color from the cheapest, almost black article known as "black strap," to the finest, which is light yellowish brown. When refined, it is brilliant and transparent, and is known as syrup.

All grades, but especially the higher, are adulterated extensively with glucose syrup. This reduces the sweetening power, but gives body and a finer appearance. The fraud is detected readily by the use of the polariscope, since the adulterated article gives a much higher reading, and on inversion, instead of giving left polarization, continues to give a reading to the right almost as high as before. Another, and, from a sanitary point of view, a more important adulterant of molasses, is the protochloride of tin, known also as "tin crystal" and "salts of tin." This is added for the purpose of reducing the amount of color, thus giving a fictitious added value. It combines with part of the coloring matters, and the resulting compound separates and tends to deposit. Thus a large proportion of the amount added to a hogshead may be found in the "foot," or sugar sediment, which is used quite commonly in the making of cheap candies, such as cocoanut taffy. Only a part, however, is deposited, and hence a specimen thus adulterated will yield notable traces of the salt on incineration and analysis. It is useless to attempt to separate the tin in the ordinary way without previous incineration, since the organic matters present prevent precipitation of the sulphide. Inasmuch as the protochloride of tin is an irritant poison, and since its addition can serve no legitimate useful purpose, this form of adulteration should be prohibited and punished. Sometimes tin is present in molasses, not as an adulterant, but because of a practice, followed by some makers of crude sugar, of treating their product with this agent to improve its color before it leaves the centrifugal machines, and thus it finds its way into the by-product.

HONEY.

Honey is classed sometimes as an animal food, since it is a product stored up by bees, but it can hardly be so considered, since it is obtained from the nectaries of flowers, although during its storage in the bee's

crop it undergoes some change. After this alteration by the secretions of the crop, it is disgorged and deposited in the cell of the honey-comb.

Honey is a concentrated solution of sugars, chiefly dextrose and lævulose, with small amounts of sucrose and mannite, containing also small amounts of wax, organic acids, proteids, mineral matter, pollen, and odorous and other principles. The flavor, color, and odor vary according to the nature of the flowers from which the honey is obtained. Sometimes, when derived from poisonous plants, it has toxic properties; this fact has been noted by both ancient and modern writers. Xenophon, for example, has recorded most serious symptoms of intoxication due to its ingestion, and a number of small outbreaks resembling ptomain-poisoning have been reported by recent writers in this country. Xenophon[1] says: "As to other things here, there was nothing at which they were surprised; but the number of beehives was extraordinary, and all of the soldiers that ate of the combs lost their senses, vomited, and were affected with purging, and not one of them was able to stand upright; such as had eaten only a little were like men greatly intoxicated, and such as had eaten much were like madmen, and some like persons at the point of death. They lay upon the ground, in consequence, in great numbers, as if there had been a defeat; and there was general dejection. The next day not one of them was found dead; and they recovered their senses about the same hour they had lost them on the preceding day; and on the third and fourth days they got up as if after having taken physic."

Dioscorides speaks of a kind of honey that made those that ate it mad, and ascribes its poisonous properties to the great abundance of rose-laurel and other similar poisonous plants. Strabo speaks of honey that made men stupid and melancholy; and Diodorus, of a certain kind in Colchos which produced such profound weakness in those that ate it "that they appeared for a whole day together like dead men."

Honey from the flowers of the yellow jasmine has been known to produce serious and even fatal results, and that derived from a species of rhododendron growing in the neighborhood of the Black Sea has long been recognized as poisonous.

The power of honey to exert a medicinal influence is sometimes turned to good account. Thus, in Abyssinia, where the flowers of the cusso tree are the universal remedy for tapeworm and ascarides, with which a large proportion of the population is afflicted, swarms of bees are kept by order of King Menelek in gardens where no other plant is cultivated, and the honey which they store has been found to have all the good qualities of the drug with none of its unpalatability or unpleasant effects, such as nausea and vomiting.

By microscopic examination, which will show numerous pollen grains, one can determine easily from what kind of flower a honey was gathered.

Honey contains about 73 per cent. of sugar. In consequence of the preponderant influence of the lævulose on the rotation of the

[1] Anabasis, Book IV., Chap. 8.

plane of polarized light the polariscope reading of a pure sample is almost always to the left; when not to the left, the reading is not more than a few degrees to the right. The percentage of water averages about 18 or 19; occasionally specimens are found to contain as much as 25.

Honey is an important sugar food; it is very agreeable to the taste and easily assimilated. On account of its comparatively high price, it is very subject to adulteration with glucose and cane sugar. That which is sold in the comb, the comb still in its frame, is almost invariably genuine. The extracted honeys sold in bottles and tumblers are very commonly mixtures of the genuine article with glucose or cane sugar, and often contain no honey whatever. In order to convey the idea of genuineness, it is a common practice to insert a small piece of comb. At least one ingenious fabricator of glucose-honey has been known to add to each tumbler of his product a dead bee, to serve as a silent false witness of its origin.

The detection of adulteration with glucose or cane sugar is an easy matter, since all samples so made give a strong reading to the right on polariscopic examination. On inversion of the sample, the right-handed reading persists if the adulterant is glucose, and is changed to the left if cane sugar. It is said that inverted cane sugar sometimes is mixed in proper proportion to make an artificial honey which will give the normal polariscopic test of the genuine article; and that to imitate the latter still farther, so that microscopical examination also may attest its genuineness, pollen grains are added in sufficient amounts. The ash of such a product alone will reveal the fraud, since it will contain no phosphoric acid, while genuine honey contains about 0.03 per cent. of that substance.

CONFECTIONERY.

Candies are preparations made of sugars or substances containing them, such as molasses and honey, with or without the admixture of other food materials, such as nuts, fruits, and chocolate, starches and fats to give body and consistence, and flavoring and coloring agents. The addition of substances which serve no legitimate useful purpose, such as terra alba, which is said to be added sometimes to lend weight, and of injurious colors and flavors, may properly be regarded as adulteration; but the use of glucose sugar, cocoa butter, and other substances of a harmless nature, and possessing value as nutriment, cannot be so regarded. Many, some say most, of the cheaper candies, contain variable amounts of glucose and starch, but nothing is to be said against the use of these substances on the score of wholesomeness. The use of terra alba is supposed popularly to be very common, but numerous analyses by many chemists throughout the country show that this substance is an exceedingly uncommon ingredient of even the very cheapest candies.

The flavoring agents commonly employed are, as a rule, harmless.

The colors used, however, are not infrequently of a poisonous nature, especially in those States which have no laws against food adulteration, or which, having them, make no provision for their enforcement. These injurious coloring agents include the chromates of potassium and lead, tin lakes, and certain of the coal-tar products, such as Martius yellow, dinitrocresol, and dinitroso-resorcinol. The employment of chromate of lead and of chromate of potassium is frequently denied, but these substances, nevertheless, are used not uncommonly, and have been detected by the author in many specimens of yellow sugars used for decorating cakes, and in yellow candies made in the shape of beans. The majority of the colors used are, however, of a harmless nature.

JELLIES AND JAMS.

Jellies are semi-solid glutinous preparations made by boiling fruit juices with sugar and allowing to cool; jams are somewhat similar preparations, which include the pulp of the fruit as well as the juice.

Many of the jellies found in the shops are made with glucose syrup, cane sugar, gelatin, artificial flavorings and colors, and extracts made by boiling the refuse of canning establishments. Jams, likewise, are largely factitious, being made with glucose syrup, flavorings, colorings, various kinds of seeds, and nearly tasteless vegetable tissues, such as summer squash and boiled white turnips.

Section 5. BEVERAGES.

Stimulant Beverages Containing Alkaloids.

These include tea, coffee, and cocoa, and certain others not used to any large extent in this country. The alkaloids of these products are known, respectively, as theine and caffeine, which are chemically identical, and theobromine, which is very closely related.

TEA.

The virtues of tea were discovered, according to Chinese tradition, more than 2700 years before the Christian era. It was used first in England in the seventeenth century (about 1657), and came there into general use about 1675. It was introduced into America in 1711.

Tea is the dried leaf of a shrub, *Thea Chinensis*, indigenous to China and other parts of Asia, and cultivated in India, Japan, and Ceylon. Formerly, the varieties of the plant produced by different methods of long cultivation were believed to be distinct species, and were known as *T. Bohea*, *T. viridis*, etc. The differences in the varieties found in commerce depend upon the age of the leaves when gathered and their position on the stem, and upon special methods of drying and preparing them for the market. The choicest varieties, for example, are those which include only the terminal leaves, and the poorest those made up of the largest and coarsest leaves from the lower end of the twig.

Tea is classed commonly as green or black. Both kinds come from the same shrub, but are different in point of age, and are cured in different ways. Green tea is made from young leaves, which are roasted quickly shortly after being gathered, and then rolled and again roasted. Black tea is from older leaves, which are allowed to wilt, and then are gathered into heaps and left without farther manipulation for about a half day, during which time they undergo a fermentative process and change color. Next, they are rolled by hand and then heated, and these processes may be repeated several times alternately. Finally, they are dried slowly over burning charcoal.

The composition of tea is very variable, and it is impossible to give figures which may be accepted as indicating the approximate constitution of a typical specimen. König has collected 16 analyses, which give the following averages:

Moisture	11.49
Nitrogenous matters	21.22
Theine	1.35
Volatile oil	0.67
Fat, resin, etc.	3.62
Gum, dextrin, etc.	7.13
Tannin	12.36
Other extractives	16.75
Fiber	20.30
Ash	5.11
	100.00

But it should be said that the variations in the amounts of individual constituents of these 16 specimens are very wide: for instance, water, 4.59 to 16.06; theine, 0.40 to 4.94; tannin, 4.10 to 20.88; fiber, 15.11 to 25.06. Dragendorff found, in 23 specimens, from 1.36 to 3.09 per cent. of theine, 7.10 to 12.66 of moisture, and from 24.80 to 44.50 per cent. of total soluble constituents. The ash of pure tea is fairly constant in amount, and almost never reaches as high as 7 per cent.; usually, between 5 and 6 per cent.

Tea should be used only in the form of an infusion, made by pouring boiling water upon the requisite amount of leaves, and allowing it to stand a short while to "draw." It is used not uncommonly in the form of a decoction; that is, by boiling. This process is objectionable in two ways: first, the delicate aroma is lost by the expulsion of the very volatile essential oil; and second, the leaves are made to yield all their tannin and other extractives, which tend to bring about, sooner or later, derangement of the digestive function and a catarrhal condition of the stomach. The finest and most delicate portion of an infusion is that which is poured off within three or four minutes, for in this will be found a maximum of flavor with a minimum of bitterness and astringency. The excellence of an infusion is influenced considerably by the character of the water, which, if very hard, is slow in extracting the desirable soluble constituents, while, if very soft, it extracts not only these, but far too rapidly the less desirable principles.

When properly made, tea in moderation is a wholesome, agreeable,

and refreshing stimulant beverage, particularly grateful in conditions of mental or physical weariness. Used in excess, it exerts a harmful influence upon the nervous system, and in a too strong form injures the digestive tract and function.

The abuse of tea as a beverage leads, according to Bullard,[1] to ringing in the ears, tremor, nervousness, headache, neuralgia, hysteria, irregularity of the heart, dyspnœa, dyspepsia, and constipation.

Dr. Hayes, the Arctic explorer, has testified to the value of tea and coffee in enabling men to endure cold and hardship of all sorts, tea being especially soothing at the end of a hard day's work.

While tea by itself can hardly be looked upon as an article affording any important amount of nutriment, as commonly consumed it serves as a vehicle for other substances, as sugar, milk, and cream, having high nutritive value.

Adulteration of Tea.—It is commonly stated and generally believed that tea is adulterated extensively with other kinds of leaves, including those of the beech, sloe, willow, and hawthorn; but at the present time, it is extremely improbable that such adulterants ever are mixed with tea known to be intended for export to this country. Whatever the conditions may have been prior to the enactment of the national law governing tea importation, the fact now is that our tea supply is practically free from this form of adulteration. The detection of spurious tea leaves would be an easy matter, since the genuine have a very characteristic appearance which can hardly be confused with that of any of the possible substitutes; and even when broken into small bits, the characteristic differences in venation and serration, and in the stomata as well, are plainly discernible.

More probable forms of adulteration include the admixture of wholly or partially exhausted leaves; the addition of astringent matters, such as catechu, to lend color and apparent strength to the infusion; the presence of foreign mineral matter; and the practice of "facing."

The presence of any large proportion of exhausted leaves can be detected by the low amount of total soluble extract and by the small amount of soluble ash, which should not be less than 3 per cent. of the weight of the leaves. The presence of important amounts of accidental or added mineral matters is shown in the total ash, which in a genuine specimen rarely amounts to 7 and never to 8 per cent. The substances most often found are sand and soapstone; the first named is found sometimes in amounts exceeding 25 per cent.

Catechu is applied occasionally to exhausted tea leaves with the aid of solutions of gummy matters, for the purpose of adding astringency and color to the infusion. Teas so treated have but little, if any, of the true aroma, and their infusions yield a sediment in which the particles of catechu can readily be seen.

The object of "facing" is to make the product appear to be of greater value, and the practice is, therefore, properly speaking, one which comes within the definition of fraudulent adulteration. Damaged

[1] Boston Medical and Surgical Journal, April 8, 1886, and September 8, 1887.

or otherwise inferior leaves are treated with Prussian blue, plumbago, indigo, and other substances, and the small amount which adheres improves their color and general appearance. This amount is too small to be of any sanitary significance. The presence of facing materials may be detected by the use of the microscope and by chemical analysis.

COFFEE.

Coffee is the seeds of the *Coffea Arabica*, dried and deprived of their fleshy covering. The fruit is a small pulpy berry containing, usually, two seeds. The tree is said to have originated in Abyssinia, where, however, in the seventeenth century there were few, if any, specimens, and to have been introduced into Arabia in the fifteenth century. It is now grown very extensively in Brazil, Java, Peru, Ceylon, West Indies, and other hot countries. The first European to mention it was Prosper Alpinus, of Padua, who included it in an account of Egyptian plants, published in 1592. The first work devoted wholly to coffee was a small Latin treatise, *De saluberrima potione cahue*, by Faustus Nairo, Rome, 1671. Coffee was first sold in London by a Levantine, in 1650, and some years afterward was introduced into France. The first whole cargo introduced into this country arrived in 1809, but coffee houses were licensed in Massachusetts as early as 1715.

The world's production of coffee for the year ended June 30, 1900, was estimated at almost 900,000 tons.[1] This country alone consumes more than the whole of Europe: in 1897 we consumed 318,170 tons against 305,150. The total consumption by Germany was 136,390; by France, 77,310; by England, 12,420; and by Italy, 12,500 tons.

As is the case with tea, coffee must undergo a process of roasting before it is fit for use, although it is said that the Arabians and other Eastern peoples make a decoction of the raw article and swallow the grounds as well as the liquid. The roasting is conducted at about 200° C. until the natural color, which is greenish, grayish, or drab, is changed to a rich dark brown. During the process, certain volatile aromatic principles are developed, the alkaloid caffeine is dissociated from its union with tannin, the moisture is very largely expelled, the sugar is caramelized, gases are formed (largely carbonic dioxide) which cause the berry to swell, and much rupturing of the cell layers occurs. The berry thus loses in weight and gains in bulk. The process must be conducted carefully, else the quality will not be what is desired, since if the roasting is not pushed sufficiently far, there will be insufficient development of aroma; and if it is carried too far, the volatile matters are expelled and the product acquires an unpleasant taste. On account of the volatile nature of the aromatic principles developed, coffee should be roasted only as the demands of commerce make it necessary. On long keeping, except in hermetically sealed containers, it undergoes extensive deterioration. For the same reason, the roasted berries should be ground only as needed.

[1] Consular Reports, Vol. LX., p. 258.

Coffee contains less caffeine (theine) than is found in tea; thus, Dragendorff found the amount in 25 samples to vary between 0.64 and 2.21 per cent., whereas in about the same number (23) of samples of tea, the range was 1.36 to 3.09. It contains considerable amounts of fat, generally over 12 per cent., about the same amount of nitrogenous matters, small, quite unimportant amounts of sugars, gummy matters, and other substances, and about 40 per cent. of fiber.

Coffee is used in infusion and as a decoction. Like tea, it loses its pleasant aroma when boiled, but its decoction is less bitter and astringent than that of tea. In order to enjoy both the fragrance of an infusion and the strength and body of a decoction, it is not an uncommon practice to make first the one and pour it off, and then, with a fresh portion of water, to boil the grounds for a few minutes, and then to mix the two liquids together.

Coffee acts as a decided stimulant to the nervous system, enables one better to perform arduous work, and diminishes the sense of fatigue. In small amounts, it increases the force and frequency of the pulse, but taken in excessive quantities, it causes palpitation and intermission, besides general nervousness and derangement of digestion. It has a marked inhibitory influence on gastric digestion, and is more oppressive to the stomach than tea and, hence, should be used with caution by dyspeptics. With some persons it stimulates peristalsis, and thus acts as a gentle cathartic. It increases the secretions of the skin and kidneys.

Coffee is adulterated very extensively with a variety of substances of widely different nature, including chicory, dandelion, and other roots, roasted cereals and legumes, sawdust, date stones, red slate, acorns, and other cheap articles. It is not alone in the ground form that it is falsified, for even the beans are imitated with mixtures of flour and other materials, moulded to the correct shape and carefully roasted and colored.

The detection of adulterants in coffee requires but little time. Of great assistance is the fact that coffee contains absolutely no starch, while most of the commoner adulterants contain it in abundance. Therefore, if a specimen under examination is boiled and filtered, and the filtrate gives a dirty blue reaction with test-solution of iodine, one may be sure that adulteration has been practised. But not all of the adulterants are starchy in their nature and, therefore, other examination is necessary. Microscopical examination will detect not only the starchy, but the non-starchy matters as well. Under the microscope, ground coffee has a characteristic appearance which cannot be mistaken for anything else. Chicory and other roots, date stones, and all other berries and seeds have their own characteristics. For the mere determination of the question of purity, only a knowledge of the microscopical appearance of coffee itself is required, and this is acquired easily and quickly by direct study. For the identification of the adulterants present, one necessarily should be familiar with the appearance of all of the substances used.

Chicory is the root of the *Cichorium intybus*, a perennial herb, grow-

ing wild and extensively cultivated in this country and in Europe. The roots are cleaned, cut into pieces, dried in kilns, roasted in iron cylinders, and ground into a coarse powder. Like coffee, chicory when roasted contains a volatile principle and a bitter. It is used both as an adulterant and as a substitute for coffee. Mixed with coffee, it lends both color and flavor to the infusion, and by many is regarded as a desirable addition. It itself is subject to adulteration by cheaper roots, such as mangelwurzel and dandelion.

Coffee and chicory behave very differently when thrown into cold water: the former floats and retains its firm consistence, while the latter absorbs water very quickly and sinks, and in its descent leaves streaks of color. Coffee which has been roasted too much will, however, sometimes sink, and chicory which has been treated with fatty substances will float. Mixtures of the two can often be detected by the difference in resistance when placed between the teeth. The particles of coffee are much harder than those of chicory, which yield very readily to pressure and also have a sweetish taste.

Inferior and damaged raw coffees not infrequently are colored and faced, in order that they may be improved in appearance or be made to imitate better grades. The facing agents used are mixtures containing variable amounts of ultramarine, indigo, clay, gypsum, chromate of lead, and coal dust.

According to G. Wirtz,[1] inferior grades of coffee are treated largely at Antwerp, Rotterdam, Hamburg, Bremen, and elsewhere, by washing, coloring, and finally drying by centrifugation with sawdust, the result being a fine white product of an apparently greater value.

Package coffees sold under various names, such as "French Breakfast Coffee," "Vienna Coffee," and "Eureka Breakfast Coffee," are rarely anything more than roasted and ground cereals and peas. It is to be said, however, that their character usually is indicated in the directions for use printed on the labels, which commonly begin by advising the use of "a third more than you would use of genuine coffee." Microscopical examination and the iodine test will reveal their composition very quickly.

COCOA.

Cocoa, a corruption of *Cacao*, and in no way related to the cocoanut, is derived from the seeds of the *Theobroma cacao*, a native of tropical America. It is estimated that the annual production of the seeds amounts to about 150,000,000 pounds, more than a fifth of which is exported by Ecuador alone. Nearly a fifth of the annual crop is consumed within the United States.

The fruit of the cocoa tree is a pod, about a foot long and half as wide, filled with "beans," or "chocolate nuts," about as large as almonds, imbedded in five rows of from four to ten each in a pulpy matrix. When ripe, the pods are gathered and collected into heaps, and left for a day or longer; then they are cut open and deprived of

[1] Zeitschrift für Untersuchung der Nahrungs- und Genussmittel, 1898, p. 248.

the seeds, which are allowed to undergo a process of fermentation in earthen vessels or in holes in the ground. This process, which must be regulated very carefully, has for its object the removal of an acrid, bitter taste and consequent improvement in flavor. Sometimes, the seeds are dried in the sun as soon as removed, but the product is then of much less value; sometimes, the entire pod is buried until the pulp becomes rotten and softened. When the fermentation process is completed, the seeds are dried carefully in the sun, and then become hard, brittle, and reddish or reddish brown in color.

In the preparation of cocoa for the market, the seeds first are cleaned and carefully roasted. As is the case with coffee, the roasting must be carried to a certain point to insure the development of the desired flavor, but not so far beyond as to impair it. During this process, the thin husks of the seeds become more detachable, and before the next operation they are removed. Then the seeds are crushed lightly and freed from their hardened germs, and in this form are known as "nibs." These are ground in a special form of mill into a paste ("flake cocoa"), which is moulded into cakes and allowed to harden. In this form, the product is known as plain chocolate. The sweet and flavored chocolates are made with the addition of sugar, vanilla beans, cinnamon and other spices. Inferior vanilla chocolate is made with artificial vanillin and coumarin, in place of the far more expensive and better flavored vanilla bean.

For the preparation of powdered cocoa, it is necessary to remove a part of the oil, which, when present in its normal amount, favors caking. This removal is accomplished by hydraulic pressure, and the paste is then passed through sieves of exceedingly fine mesh.

The so-called soluble cocoas are prepared with sugar and starches, particularly arrowroot, but the cocoa itself is not soluble in water. The apparent solubility is due to the fineness of the powder and to the increase in the specific gravity of the liquid due to the sugar in solution, both these conditions favoring prolonged suspension without sedimentation. Some of the Dutch soluble cocoas are treated with alkalies, for the removal of the crude fiber and for their effect upon the coloring matters. These cocoas thereby lose part of their natural flavor, but the loss is made up somewhat by the addition of fragrant foreign matter.

Cocoa was introduced into Europe by the Spaniards after their invasion of Mexico under Cortez, in 1519. It was not known in England until 1657, when it was sold first in London by a Frenchman. In this country, it first was prepared and sold at Danvers, Massachusetts, in 1771, from raw material brought from the West Indies by the fishermen of Gloucester.

Unlike tea and coffee, which in themselves can hardly be regarded as adding any nutriment to the diet, cocoa is an exceedingly valuable food, which possesses the advantage of much nutriment in small bulk, and hence is particularly suited to the needs of those engaged in expeditions removed from civilized centers. It makes a wholesome, agreeable, stimulant beverage, and is eaten in the form of chocolate,

and as an addition to cakes, puddings, and other compounds. The cocoa nibs and plain chocolate contain about 50 per cent. of a whitish solid fat of agreeable taste and smell, commonly known as cocoa butter. It contains variable amounts of the alkaloid theobromine (dimethylxanthine), which is related very closely to caffeine and theine (trimethylxanthine), and has nearly the same physiological action, although somewhat less stimulant and rather more diuretic. The amount is said to average about 1.50 per cent. Cocoa is rich in nitrogenous matter, contains more than 10 per cent. of a starch with small round granules, and about 3.50 per cent. of ash, which is largely phosphate of potassium.

Sixteen analyses of the kernels, compiled by König, give the following averages:

Water	3.63
Proteids	13.49
Fat	49.32
Starch	13.25
Extractives	13.18
Fiber	3.65
Ash	3.48
	100.00

The husks, commonly known as "shells," are used in the preparation of a cheap and wholesome beverage. They contain little fat, but are about equal to cocoa in nitrogenous matter, and contain more than 40 per cent. of nitrogen-free extractives.

Cocoa and chocolate are subject to extensive adulteration with substances having much less commercial value, though perhaps equally nutritious. Among those used, are starches of various kinds, as wheat, rye, potato, arrowroot, and rice, sugar, vegetable oils, mutton tallow and other fats, Venetian red, clay, and brick dust. Various flavorings are employed, such as vanillin, coumarin, clove, mace, cardamom, and nutmeg; but unless these are used under the name of vanilla or of other flavorings than themselves, they cannot be regarded as adulterations.

Fermented Alcoholic Beverages.

BEER.

Beer is the generic term which includes all fermented drinks made from malt—lager beer, ale, porter, and stout. As commonly understood, beer is an infusion of malted barley, flavored with hops and fermented with yeast; but on account of the fact that wholesome substitutes for malt and hops may be employed in its manufacture, it is defined also as a "fermented saccharine infusion to which some wholesome bitter has been added." In this country, the term beer is restricted commonly to the product generally known as lager beer. Porter is a beer with a high percentage of alcohol, and is made from malt dried at a high temperature. Stout contains less alcohol and hops, but more malt extract. Ale is a pale beer containing more hop extract

and less malt extract than porter or stout, and brewed by "top fermentation."

Beer was made by the Egyptians many centuries before the Christian era. It is related that, for public reasons, the suppression of beer-shops was attempted by their government more than forty centuries ago. The art of brewing was taught by them to the ancient Greeks and Romans; thus, beer was a common drink in Greece prior to 700 B. C., and was one of the principal beverages of the soldiers of Cæsar. In the time of Tacitus, it was in common use in Germany; and Pliny speaks of its use in Spain. The ancient Britons, at the time of the Roman conquest, made it from barley. At the time of the Norman conquest, the words beer and ale meant in England the same thing: a drink made of malt without hops. Later, the word beer fell into disuse; but in the fifteenth and sixteenth centuries, after the introduction by the Flemish of beer made with hops, the term was revived, and then meant hopped ale. The use of hops was forbidden in 1530 by Henry VIII., who regarded them as an adulterant, and in the first year of the reign of Richard III., the authorities of London laid a fine of 6s 8d on every barrel of beer containing them. Later, this was reduced one-half.

The prejudice against the use of hops in brewing is expressed by one of the earliest English writers on dietetics, Andrew Boorde,[1] who says: "Ale is made of malte and water; and they the which do put any other thynge to ale than is rehersed, except yest, barme, or godesgood, doth sofysticat theyr ale. Ale for an Englysshe man is a natural drynke. Ale must haue these propertyes: it must be fresshe and cleare, it muste not be ropy nor smoky, nor it must haue no weft nor tayle. Ale shuld not be drunk under v. dayes olde. Newe ale is vnholsome for all men. And sowre ale, and deade ale the which doth stande a tylt, is good for no man. Barley malte maketh better ale than oten malte or any other corne doth: it doth engendre grose humoures; but yette it maketh a man stronge. Bere is made of malte, of hoppes, and water: it is the naturall drynk for a Dutche man. And nowe of late dayes it is moche vsed in Englande to the detryment of many Englysshe men; specyally it kylleth them the which be troubled with the colycke, and the stone, & the strangulion; for the drynke is a colde drynke; yet it doth make a man fat, and inflate the bely, as it doth appere by the Dutche mens faces & belyes. If the bere be well serued, and be fyned, & not newe, it doth qualyfy the heat of the lyuer."

The ancient Germans made beer from all kinds of grains, and for flavoring used oak bark, sage, and leaves of the laurel, ash, and tamarisk. Hops were used more or less from the ninth century, and came into general use in the eleventh.

Beer being the common drink of most European peoples before the establishment of colonies in America, it followed naturally that the early settlers of this country brought the art of brewing with them. In 1629, the cultivation of hops had been carried on for some time in

[1] A Compendyous Regyment, or A Dyetary of Helth, made in Mountpylier, compyled by Andrewe Boorde of Physyche Doctour, London, 1542.

New Amsterdam, and hop roots were sent for from England by the authorities of Massachusetts. In nearly all the colonies, the brewing of beer was regarded as quite as essential an accomplishment of women as the ability to make good bread.

The first law regulating the sale of alcoholic beverages in Massachusetts was made in 1633; it prescribed that no person should sell wine or spirits without a permit, but made no reference to beer. In the following year, it was ordered that no one should charge more than a penny for a quart of beer, and in 1637, that no inn-keeper or victualler should sell any intoxicating drink but beer; and this they were prohibited from brewing themselves, but must obtain from a licensed brewer. In the following year, owing to the fact that the only one of this class was unable to meet the demand, they were allowed to conduct the process themselves. In 1649, it was ordered further that every inn-keeper and victualler should keep always on hand a supply of good, wholesome beer. In 1651, the court undertook to stimulate the production of a better grade of beer in the belief that thereby the growing tendency to the use of wine and spirits and the increasing habit of drunkenness would be checked, and permission was granted to charge one, two, and three pence per quart, according to the amount of malt used per barrel.

A duty of a shilling per bushel of imported malt, imposed in 1654, called forth a protest from Boston merchants, on account of the very great importance of beer as a beverage of the people. In the following year, in order to promote home production of malt, importation was prohibited, but this order was repealed in 1660. In 1667, the use of molasses as an adulterant of beer was punishable by a fine of five pounds. Similar laws relating to beer were passed from time to time by the authorities of all the original colonies.

Process of Manufacture of Beer.—The first step in the brewing of beer is the preparation of the malt. The barley first is steeped in water for several days, and then is removed and arranged in heaps, which, after a time, are spread out and turned repeatedly until germination has proceeded to the requisite extent. Next it is dried in kilns at a temperature below or about 90° F., and then is heated to from 125° to 180°, according to the color desired. This process develops flavor, completely checks germination, and determines the commercial character of the product. The steeping of the malt is done best in water containing considerable of the mineral salts that cause hardness; a soft water exerts too much solvent action on the proteid matters, which, soon after extraction, are likely to undergo decomposition. During the progress of germination, the ferment diastase is developed, and proceeds to convert the starch into dextrin and maltose. After the germs and rootlets have been removed by proper screening and sifting, the malt is crushed, and then an infusion, the "wort," is made with water at about 160° F. This is drawn off from the exhausted malt, and then boiled for an hour or two with hops, which, besides giving a characteristic bitter flavor, assist in clarification

by the action of their contained tannin on some of the proteid matters. Then the boiled bitter wort is cooled rapidly, run into vats, mixed with yeast, and allowed to ferment for several days, during which time alcohol and carbonic acid are formed from the maltose. The nature of the product is influenced very largely by the purity of the yeast and by the method of fermentation followed. Top fermentation is carried on rapidly, and at a comparatively high temperature, the yeast growing at the surface; in bottom, or sedimentary, fermentation, the yeast grows at the bottom, the process is slower, and is carried on at a lower temperature. The chief advantage of the employment of yeast which grows at a low temperature is that other, perhaps undesirable, growths may be unable to proceed. Whatever the process of fermentation followed, not all the sugar should be allowed to be converted, for then the flavor would be not what it should, and the keeping qualities would be impaired. On the completion of fermentation, the beer is separated from the yeast and transferred to vats, where it is clarified. As clarifying agents, a variety of materials are used, the chief of which are chips or shavings of certain woods, as hazel or beech, which attract and hold the particles which cause turbidity. These materials affect in no way the taste of the beer. Other substances used include gelatin, isinglass, flax-seed, and carrageen. After clarification is accomplished, the product is stored for a time in storage casks, where it undergoes a further slow fermentation at a low temperature, after which it is ready for use.

Substitutes for Barley Malt.—While barley is recognized universally as the grain best suited to the brewing of wholesome beer, any other cereal may be used. Sometimes, unmalted grains are added to the malt before the infusion is made, for the diastase of the malt is capable of converting not only the starch with which it naturally is associated, but a large amount of other starches; and so, rice, corn, and other cereals may be employed. Glucose and cane sugar are used somewhat, but the product is decidedly inferior in quality, since these substances are lacking in some of the elements, as proteids and mineral matters, which contribute to the desirable character of the best beers.

Concerning the use of glucose, which adds strength to the wort, there can be no objection on the score of being in any way deleterious to health. The popular belief in the unwholesomeness of glucose made from corn starch led the U. S. Treasury Department, in 1882, to request an investigation of the subject by the National Academy of Sciences. This was conducted by a committee of eminent scientists, including Professors Gibbs, of Harvard; Brewer, of Yale; Remsen, of Johns Hopkins; Barker, of Pennsylvania; and Chandler, of Columbia, whose conclusions were: that the processes employed in the manufacture are unobjectionable; that the product is of exceptional purity, and in no way inferior in healthfulness to cane sugar; and that there was no evidence adduced to show that, even when taken in large quantities, either in its natural condition or fermented, it has any injurious

effects upon the system. From a recent experience in England it appears, however, that not all manufacturers produce a pure article; and that if sulphuric acid made from arsenical pyrites is used in the process, the resulting sugar may contain sufficient arsenic to cause serious and even fatal poisoning. In November, 1900, Dr. E. S. Reynolds[1] called attention to a number of cases, characterized by paralysis, wasting of certain muscles, and loss of function of certain sensory nerves, which, after considerable study, he decided to be arsenical poisoning. Shortly afterward, an increase was noticed in the number of cases of, and deaths from, peripheral neuritis in different cities and towns, and it appeared that, in Manchester and Salford alone, there were about 3000 cases, and that the victims were drinkers of beer. The beer in use was examined, and found to be distinctly arsenical, and it was learned that, in its manufacture, glucose and invert sugar, made at a factory near Liverpool, had been employed. Specimens of the glucose were found to contain from 0.02 to 0.05 per cent. of arsenious oxide, and examination of the various beers made therefrom showed from 0.10 to 1.50 grains of arsenic per gallon. The amount of beer consumed by the victims varied from a pint to two gallons per day; many drank a gallon each. A parliamentary commission, appointed to investigate the matter, reported finding from 0.56 to 9.17 grains of arsenic per pound of glucose, 1.40 to 4.34 grains per pound of invert sugar, 0.25 to 3 grains per gallon of beer, and 1.40 to 2.60 per cent. of arsenic in the sulphuric acid with which the sugars were made. Between November 25, 1900, and January 10, 1901, there were no less than 36 deaths in Manchester alone, which were attributed to arsenical poisoning. The symptoms observed in this extensive outbreak began, as a rule, with disturbances of digestion, followed soon by laryngeal and bronchial catarrh and acute skin eruptions, and then by disturbances of sensibility and motor paralysis. The cases were grouped into those in which all the above symptoms were fairly well marked, and those in which the principal lesions were, respectively, of the skin, heart, and liver, and paralytic.

Substitutes for Hops.—Various substances have from time to time been reported as being used in place of hops to give bitterness to beer. These include nearly everything having a bitter taste, such as strychnine, chirata, calumba, cocculus indicus, aloes, and picric acid. Cocculus indicus was mentioned in Holland as early as 1620 as an adulterant. This and its active principle picrotoxine, and picric acid, have been employed occasionally in England and elsewhere; but at the present time, it is safe to say, none of these substances is used. Of 476 samples of beer examined for the State Board of Health of New York, in 1885, not one was found to contain any hop substitutes whatever.

No objections can be alleged against such wholesome bitters as quassia, gentian, calumba, and chirata. Evidence that they ever are employed is exceedingly slight. As a matter of fact, there is no satisfactory substitute for hops, which give not alone bitterness, but other flavors and a

[1] British Medical Journal, Nov. 24, 1900.

peculiar aroma, due to the resinous matter which they contain. In the sixteenth and seventeenth centuries, various other flavorings were used, such as sage, coriander, laurel leaves, pepper, grains of Paradise, orris, and essential oils.

Physical Properties and Chemical Composition of Beer.—Beer should be perfectly clear and bright. The presence of any turbidity denotes either imperfect brewing or the occurrence of undesirable decomposition processes. The latter are accompanied generally by disagreeable odors. The taste should be pleasantly bitter and inclining to sweetness rather than to acidity. There should be a sufficient amount of carbonic acid to make a pleasant impression in the mouth, such as is not produced by flat beer. The specific gravity ranges from about 1.005 to 1.025, averaging below 1.020. In bock beer, which is a special brew containing a considerable increase in malt extractives, the specific gravity is notably higher, running as high as 1.035, and averaging more than 1.021.

The most important constituents of beer are the extract and alcohol. The extract includes all of the non-volatile matters in solution, and consists of proteid matters, dextrin, sugar, hop resin, and other substances left as a residue on complete evaporation. The amount is variable; it is highest in porter, stout, and bock beer, and lowest in the light-colored lager beers. In the former, it averages about 7.50, and in the latter, about 5.50 per cent. Twenty-eight specimens of American beers, ales, and porter collected in Washington, and analyzed by Mr. C. A. Crampton,[1] averaged 5.53 per cent.

The average extract of 182 analyses of specimens of beers of the lighter kinds, compiled by König, is stated at 5.49 (range, 1.98–9.23); of 211 lager beers of all kinds, at 5.78; of 50 export beers, at 6.48; and of 56 bock beers, at 7.20.

The amount of alcohol is also variable. The specimens examined by Crampton, averaged 4.63 per cent. by weight and 5.79 by volume. The light beers above mentioned (König) averaged 3.46 per cent. by weight; the second group, 3.95; the third, 4.31; and the fourth, 4.74.

Adulteration of Beer.—Beer is supposed popularly to be extensively adulterated, and the substances alleged to be in common use make up a list remarkable for length and variety, including such poisonous drugs as opium, belladonna, henbane, and strychnine, many of the aromatics and aromatic bitters, corrosive acids, drastic cathartics, and many other substances. The actual adulteration of beer, however, is restricted practically to the use of preservatives, such as sodium fluoride and salicylic acid, of sodium bicarbonate to correct acidity and to increase the "bead," and of salt to correct bad taste and to inspire thirst for more.

The use of preservatives is the only form of adulteration which is of practical hygienic importance, and in several countries is punishable by heavy penalties. In Germany, preservatives are interdicted very strictly, except in beer intended for export; and the permission

[1] U. S. Department of Agriculture, Division of Chemistry, Bulletin 13, p. 282.

extended is accepted so freely that it is rare to find in this country a specimen of German bottled beer which does not contain a liberal dose of salicylic acid. Many American brewers use this agent with a generous hand, under the benevolent plea that it is a prophylactic against rheumatism. By the same process of reasoning, one might contend just as well that opium in food and drink would prevent pain, and biniodide of mercury keep the system free from syphilitic infection.

Analysis of Beer.

In the analysis of beer, the most important processes are the determination of the percentage of alcohol and of extract, and the detection of preservatives.

Determination of Alcohol.—For the determination of the percentage of alcohol, a sufficiently large portion of beer should be shaken in a capacious flask until the carbonic acid is expelled, and then a measured volume should be subjected either to distillation or to partial evaporation in an open vessel.

(*a*) **Determination by Distillation.**—Introduce into a flask connected with a Liebig condenser 100 cc. of the well-shaken beer, at 60° F., and distil into another flask connected with the discharging end of the condenser by means of a bent glass tube. Continue the distillation until somewhat more than 50 cc. of distillate have been collected, when all of the contained alcohol will have been expelled and condensed. Add sufficient water to the distillate to make 100 cc. at 60° F., determine its specific gravity by means of a picnometer or Westphal balance (a specific gravity spindle is not sufficiently accurate), and ascertain from this, by reference to the appended table, the percentage of alcohol by weight or volume.

(*b*) **Determination by Open Evaporation.**—This method involves less manipulation and gives equally accurate results. The specific gravity of the beer is determined first in the manner above mentioned. Then place 100 cc. at 60° F. in a glass or porcelain evaporating dish, and by the application of heat drive off rather more than half the amount. Remove, cool, make up with water to the original volume at 60° F., and again determine the specific gravity. Divide the original gravity by the latter, and the result equals that of the alcohol which has been expelled. Refer to the table, and obtain therefrom the percentage of alcohol in the beer.

The following table, by Mr. Edgar Richards, is the one used by the Association of Official Agricultural Chemists:[1]

[1] U. S. Department of Agriculture, Division of Chemistry, Bulletin No. 46, Washington, Government Printing Office, 1899.

TABLES SHOWING PERCENTAGE OF ALCOHOL BY WEIGHT AND BY VOLUME.

(*Recalculated from the determinations of Gilpin, Drinkwater, and Squibb, by Edgar Richards.*)

Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.	Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.	Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.
1.00000	0.00	0.00	0.99629	2.50	1.99	0.99281	5.00	4.00
0.99992	.05	.04	622	.55	2.03	274	.05	.04
984	.10	.08	615	.60	.07	268	.10	.08
976	.15	.12	607	.65	.11	261	.15	.12
968	.20	.16	600	.70	.15	255	.20	.16
961	.25	.20	593	.75	.19	248	.25	.20
953	.30	.24	586	.80	.23	241	.30	.24
945	.35	.28	579	.85	.27	235	.35	.28
937	.40	.32	571	.90	.31	228	.40	.32
930	.45	.36	564	.95	.35	222	.45	.36
.99923	0.50	0.40	.99557	3.00	2.39	.99215	5.50	4.40
915	.55	.44	550	.05	.43	208	.55	.44
907	.60	.48	543	.10	.47	202	.60	.48
900	.65	.52	536	.15	.51	195	.65	.52
892	.70	.56	529	.20	.55	189	.70	.56
884	.75	.60	522	.25	.59	182	.75	.60
877	.80	.64	515	.30	.64	175	.80	.64
869	.85	.67	508	.35	.68	169	.85	.68
861	.90	.71	501	.40	.72	162	.90	.72
854	.95	.75	494	.45	.76	156	.95	.76
.99849	1.00	0.79	.99487	3.50	2.80	.99149	6.00	4.80
842	.05	.83	480	.55	.84	143	.05	.84
834	.10	.87	473	.60	.88	136	.10	.88
827	.15	.91	466	.65	.92	130	.15	.92
819	.20	.95	459	.70	.96	123	.20	.96
812	.25	.99	452	.75	3.00	117	.25	5.00
805	.30	1.03	445	.80	.04	111	.30	.05
797	.35	.07	438	.85	.08	104	.35	.09
790	.40	.11	431	.90	.12	098	.40	.13
782	.45	.15	424	.95	.16	091	.45	.17
.99775	1.50	1.19	.99417	4.00	3.20	.99085	6.50	5.21
768	.55	.23	410	.05	.24	079	.55	.25
760	.60	.27	403	.10	.28	072	.60	.29
753	.65	.31	397	.15	.32	066	.65	.33
745	.70	.35	390	.20	.36	059	.70	.37
738	.75	.39	383	.25	.40	053	.75	.41
731	.80	.43	376	.30	.44	047	.80	.45
723	.85	.47	369	.35	.48	040	.85	.49
716	.90	.51	363	.40	.52	034	.90	.53
708	.95	.55	356	.45	.56	027	.95	.57
.99701	2.00	1.59	.99349	4.50	3.60	.99021	7.00	5.61
694	.05	.63	342	.55	.64	015	.05	.65
687	.10	.67	335	.60	.68	009	.10	.69
679	.15	.71	329	.65	.72	002	.15	.73
672	.20	.75	322	.70	.76	.98996	.20	.77
665	.25	.79	315	.75	.80	990	.25	.81
658	.30	.83	308	.80	.84	984	.30	.86
651	.35	.87	301	.85	.88	978	.35	.90
643	.40	.91	295	.90	.92	971	.40	.94
636	.45	.95	288	.95	.96	965	.45	.98

Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.	Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.	Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.
0.98959	7.50	6.02	0.98603	10.50	8.45	0.98273	13.50	10.90
953	.55	.06	597	.55	.49	267	.55	.94
947	.60	.10	592	.60	.53	262	.60	.98
940	.65	.14	586	.65	.57	256	.65	11.02
934	.70	.18	580	.70	.61	251	.70	.06
928	.75	.22	575	.75	.65	246	.75	.11
922	.80	.26	569	.80	.70	240	.80	.15
916	.85	.30	563	.85	.74	235	.85	.19
909	.90	.34	557	.90	.78	230	.90	.23
903	.95	.38	552	.95	.82	224	.95	.27
.98897	8.00	6.42	.98546	11.00	8.86	.98219	14.00	11.31
891	.05	.46	540	.05	.90	214	.05	.35
885	.10	.50	535	.10	.94	200	.10	.39
879	.15	.54	529	.15	.98	203	.15	.43
873	.20	.58	524	.20	9.02	198	.20	.47
867	.25	.62	518	.25	.07	193	.25	.52
861	.30	.67	513	.30	.11	188	.30	.56
855	.35	.71	507	.35	.15	182	.35	.60
849	.40	.75	502	.40	.19	177	.40	.64
843	.45	.79	496	.45	.23	172	.45	.68
.98837	8.50	6.83	.98491	11.50	9.27	.98167	14.50	11.72
831	.55	.87	485	.55	.31	161	.55	.76
825	.60	.91	479	.60	.35	156	.60	.80
819	.65	.95	474	.65	.39	151	.65	.84
813	.70	.99	468	.70	.43	146	.70	.88
807	.75	7.03	463	.75	.47	140	.75	.93
801	.80	.07	457	.80	.51	135	.80	.97
795	.85	.11	452	.85	.55	130	.85	12.01
789	.90	.15	446	.90	.59	125	.90	.05
783	.95	.19	441	.95	.63	119	.95	.09
.98777	9.00	7.23	.98435	12.00	9.67	.98114	15.00	12.13
771	.05	.27	430	.05	.71	108	.05	.17
765	.10	.31	424	.10	.75	104	.10	.21
759	.15	.35	419	.15	.79	099	.15	.25
754	.20	.39	413	.20	.83	093	.20	.29
748	.25	.43	408	.25	.87	088	.25	.33
742	.30	.48	402	.30	.92	083	.30	.38
736	.35	.52	397	.35	.96	078	.35	.42
730	.40	.56	391	.40	10.00	073	.40	.46
724	.45	.60	386	.45	.04	068	.45	.50
.98719	9.50	7.64	.98381	12.50	10.08	.98063	15.50	12.54
713	.55	.68	375	.55	.12	057	.55	.58
707	.60	.72	370	.60	.16	052	.60	.62
701	.65	.76	364	.65	.20	047	.65	.66
695	.70	.80	359	.70	.24	042	.70	.70
689	.75	.84	353	.75	.28	037	.75	.75
683	.80	.88	348	.80	.33	932	.80	.79
678	.85	.92	342	.85	.37	026	.85	.83
672	.90	.96	337	.90	.41	021	.90	.87
666	.95	8.00	331	.95	.45	016	.95	.91
.98660	10.00	8.04	.98326	13.00	10.49	.98011	16.00	12.95
654	.05	.08	321	.05	.53	005	.05	.99
649	.10	.12	315	.10	.57	001	.10	13.03
643	.15	.16	310	.15	.61	97996	.15	.08
637	.20	.20	305	.20	.65	991	.20	.12
632	.25	.24	299	.25	.69	986	.25	.16
626	.30	.29	294	.30	.74	980	.30	.20
620	.35	.33	289	.35	.78	975	.35	.24
614	.40	.37	283	.40	.82	970	.40	.29
609	.45	.41	278	.45	.86	965	.45	.33

Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.	Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.	Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight-
0.97960	16.50	13.37	0.97658	19.50	15.84	0.97355	22.50	18.34
955	.55	.41	653	.55	.88	350	.55	.38
950	.60	.45	648	.60	.93	345	.60	.42
945	.65	.49	643	.65	.97	340	.65	.47
940	.70	.53	638	.70	16.01	335	.70	.51
935	.75	.57	633	.75	.05	330	.75	.55
929	.80	.62	628	.80	.09	324	.80	.59
924	.85	.66	623	.85	.14	319	.85	.63
919	.90	.70	618	.90	.18	314	.90	.68
914	.95	.74	613	.95	.22	309	.95	.72
.97909	17.00	13.78	.97608	20.00	16.26	.97304	23.00	18.76
904	.05	.82	603	.05	.30	299	.05	.80
899	.10	.86	598	.10	.34	294	.10	.84
894	.15	.90	593	.15	.38	289	.15	.88
889	.20	.94	588	.20	.42	283	.20	.92
884	.25	.98	583	.25	.46	278	.25	.96
879	.30	14.03	578	.30	.51	273	.30	19.01
874	.35	.07	573	.35	.55	268	.35	.05
869	.40	.11	568	.40	.59	263	.40	.09
864	.45	.15	563	.45	.63	258	.45	.13
.97859	17.50	14.19	.97558	20.50	16.67	.97253	23.50	19.17
853	.55	.23	552	.55	.71	247	.55	.21
848	.60	.27	547	.60	.75	242	.60	.25
843	.65	.31	542	.65	.80	237	.65	.30
838	.70	.35	537	.70	.84	232	.70	.34
833	.75	.40	532	.75	.88	227	.75	.38
828	.80	.44	527	.80	.92	222	.80	.42
823	.85	.48	522	.85	.96	216	.85	.46
818	.90	.52	517	.90	17.01	211	.90	.51
813	.95	.56	512	.95	.05	206	.95	.55
.97808	18.00	14.60	.97507	21.00	17.09	.97201	24.00	19.59
803	.05	.64	502	.05	.13	196	.05	.63
798	.10	.68	497	.10	.17	191	.10	.67
793	.15	.73	492	.15	.22	185	.15	.72
788	.20	.77	487	.20	.26	180	.20	.76
783	.25	.81	482	.25	.30	175	.25	.80
778	.30	.85	477	.30	.34	170	.30	.84
773	.35	.89	472	.35	.38	165	.35	.88
768	.40	.94	467	.40	.43	159	.40	.93
763	.45	.98	462	.45	.47	154	.45	.97
.97758	18.50	15.02	.97457	21.50	17.51	.97149	24.50	20.01
753	.55	.06	451	.55	.55	144	.55	.05
748	.60	.10	446	.60	.59	139	.60	.09
743	.65	.14	441	.65	.63	133	.65	.14
738	.70	.18	436	.70	.67	128	.70	.18
733	.75	.22	431	.75	.71	123	.75	.22
728	.80	.27	426	.80	.76	118	.80	.26
723	.85	.31	421	.85	.80	113	.85	.30
718	.90	.38	416	.90	.84	107	.90	.35
713	.95	.39	411	.95	.88	102	.95	.39
.97708	19.00	15.43	.97406	22.00	17.92	.97097	25.00	20.43
703	.05	.47	401	.05	.96	092	.05	.47
698	.10	.51	396	.10	18.00	086	.10	.51
693	.15	.55	391	.15	.05	081	.15	.56
688	.20	.59	386	.20	.09	076	.20	.60
683	.25	.63	381	.25	.13	071	.25	.64
678	.30	.68	375	.30	.17	065	.30	.68
673	.35	.72	370	.35	.21	060	.35	.72
668	.40	.76	365	.40	.26	055	.40	.77
663	.45	.80	360	.45	.30	049	.45	.81

Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.	Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.	Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.
0.97044	25.50	20.85	0.96715	28.50	23.38	0.96360	31.50	25.94
039	.55	.89	709	.55	.42	353	.55	.98
033	.60	.93	704	.60	.47	347	.60	26.03
028	.65	.98	698	.65	.51	341	.65	.07
023	.70	21.02	692	.70	.55	335	.70	.11
018	.75	.06	687	.75	.60	329	.75	.16
012	.80	.10	681	.80	.64	323	.80	.20
007	.85	.14	675	.85	.68	316	.85	.24
001	.90	.19	669	.90	.72	310	.90	.28
.96996	.95	.23	664	.95	.77	304	.95	.33
.96991	26.00	21.27	.96658	29.00	23.81	.96298	32.00	26.37
986	.05	.31	652	.05	.85	292	.05	.41
980	.10	.35	646	.10	.89	285	.10	.46
975	.15	.40	640	.15	.94	279	.15	.50
969	.20	.44	635	.20	.98	273	.20	.54
964	.25	.48	629	.25	24.02	267	.25	.59
959	.30	.52	623	.30	.06	260	.30	.63
953	.35	.56	617	.35	.10	254	.35	.67
949	.40	.61	611	.40	.15	248	.40	.71
942	.45	.65	605	.45	.19	241	.45	.76
.96937	26.50	21.69	.96600	29.50	24.23	.96235	32.50	26.80
932	.55	.73	594	.55	.27	229	.55	.84
926	.60	.77	587	.60	.32	222	.60	.89
921	.65	.82	582	.65	.36	216	.65	.93
915	.70	.86	576	.70	.40	210	.70	.97
910	.75	.90	570	.75	.45	204	.75	27.02
905	.80	.94	564	.80	.49	197	.80	.06
899	.85	.98	559	.85	.53	191	.85	.10
894	.90	22.03	553	.90	.57	185	.90	.14
888	.95	.07	547	.95	.62	178	.95	.19
.96883	27.00	22.11	.96541	30.00	24.66	.96172	33.00	27.23
877	.05	.15	535	.05	.70	166	.05	.27
872	.10	.20	529	.10	.74	159	.10	.32
866	.15	.24	523	.15	.79	153	.15	.36
861	.20	.28	517	.20	.83	146	.20	.40
855	.25	.33	511	.25	.87	140	.25	.45
850	.30	.37	505	.30	.91	133	.30	.49
844	.35	.41	499	.35	.95	127	.35	.53
839	.40	.45	493	.40	25.00	120	.40	.57
833	.45	.50	487	.45	.04	114	.45	.62
.96828	27.50	22.54	.96481	30.50	25.08	.96108	33.50	27.66
822	.55	.58	475	.55	.12	101	.55	.70
816	.60	.62	469	.60	.17	095	.60	.75
811	.65	.67	463	.65	.21	088	.65	.79
805	.70	.71	457	.70	.25	082	.70	.83
800	.75	.75	451	.75	.30	075	.75	.88
794	.80	.79	445	.80	.34	069	.80	.92
789	.85	.83	439	.85	.38	062	.85	.96
783	.90	.88	433	.90	.42	056	.90	28.00
778	.95	.92	427	.95	.47	049	.95	.05
.96772	28.00	22.96	.96421	31.00	25.51	.96043	34.00	28.09
766	.05	23.00	415	.05	.55	036	.05	.13
761	.10	.04	409	.10	.60	030	.10	.18
755	.15	.09	403	.15	.64	023	.15	.22
749	.20	.13	396	.20	.68	016	.20	.26
744	.25	.17	390	.25	.73	010	.25	.31
738	.30	.21	384	.30	.77	003	.30	.35
732	.35	.25	378	.35	.81	.95996	.35	.39
726	.40	.30	372	.40	.85	990	.40	.43
721	.45	.34	366	.45	.90	983	.45	.48

Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.	Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.	Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.
0.95977	34.50	28.52	0.95560	37.50	31.14	0.95107	40.50	33.79
970	.55	.56	552	.55	.18	099	.55	.84
963	.60	.61	545	.60	.23	091	.60	.88
957	.65	.65	538	.65	.27	083	.65	.93
950	.70	.70	531	.70	.32	075	.70	.97
943	.75	.74	523	.75	.36	067	.75	34.02
937	.80	.78	516	.80	.40	059	.80	.06
930	.85	.83	509	.85	.45	052	.85	.11
923	.90	.87	502	.90	.49	044	.90	.15
917	.95	.92	494	.95	.54	036	.95	.20
.95910	35.00	28.96	.95487	38.00	31.58	.95028	41.00	34.24
903	.05	29.00	480	.05	.63	020	.05	.28
896	.10	.05	472	.10	.67	012	.10	.33
889	.15	.09	465	.15	.72	004	.15	.37
883	.20	.13	457	.20	.76	.94996	.20	.42
876	.25	.18	450	.25	.81	988	.25	.46
869	.30	.22	442	.30	.85	980	.30	.50
862	.35	.26	435	.35	.90	972	.35	.55
855	.40	.30	427	.40	.94	964	.40	.59
848	.45	.35	420	.45	.99	956	.45	.64
.95842	35.50	29.39	.95413	38.50	32.03	.94948	41.50	34.68
835	.55	.43	405	.55	.07	940	.55	.73
828	.60	.48	398	.60	.12	932	.60	.77
821	.65	.52	390	.65	.16	924	.65	.82
814	.70	.57	383	.70	.20	916	.70	.86
807	.75	.61	375	.75	.25	908	.75	.91
800	.80	.65	368	.80	.29	900	.80	.95
794	.85	.70	360	.85	.33	892	.85	35.00
787	.90	.74	353	.90	.37	884	.90	.04
780	.95	.79	345	.95	.42	876	.95	.09
.95773	36.00	29.83	.95338	39.00	32.46	.94868	42.00	35.13
766	.05	.87	330	.05	.50	860	.05	.18
759	.10	.92	323	.10	.55	852	.10	.22
752	.15	.96	315	.15	.59	843	.15	.27
745	.20	30.00	307	.20	.64	835	.20	.31
738	.25	.05	300	.25	.68	827	.25	.36
731	.30	.09	292	.30	.72	820	.30	.40
724	.35	.13	284	.35	.77	811	.35	.45
717	.40	.17	277	.40	.81	802	.40	.49
710	.45	.22	269	.45	.86	794	.45	.54
.95703	36.50	30.26	.95262	39.50	32.90	.94786	42.50	35.58
695	.55	.30	254	.55	.95	778	.55	.63
688	.60	.35	246	.60	.99	770	.60	.67
681	.65	.39	239	.65	33.04	761	.65	.72
674	.70	.44	231	.70	.08	753	.70	.76
667	.75	.48	223	.75	.13	745	.75	.81
660	.80	.52	216	.80	.17	737	.80	.85
653	.85	.57	208	.85	.22	729	.85	.90
646	.90	.61	200	.90	.27	720	.90	.94
639	.95	.66	193	.95	.31	712	.95	.99
.95632	37.00	30.70	.95185	40.00	33.35	.94704	43.00	36.03
625	.05	.74	177	.05	.39	696	.05	.08
618	.10	.79	169	.10	.44	687	.10	.12
610	.15	.83	161	.15	.48	679	.15	.17
603	.20	.88	154	.20	.53	670	.20	.21
596	.25	.92	146	.25	.57	662	.25	.23
589	.30	.96	138	.30	.61	654	.30	.30
581	.35	31.01	130	.35	.66	645	.35	.35
574	.40	.05	122	.40	.70	637	.40	.39
567	.45	.10	114	.45	.75	628	.45	.44

Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.	Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.	Specific gravity at 60° F.	Per cent. alcohol by volume.	Per cent. alcohol by weight.
0.94620	43.50	36.48	0.94188	46.00	38.75	0.93824	48.00	40.60
612	.55	.53	179	.05	.80	815	.05	.65
603	.60	.57	170	.10	.84	805	.10	.69
595	.65	.62	161	.15	.89	796	.15	.74
586	.70	.66	152	.20	.93	786	.20	.78
578	.75	.71	143	.25	.98	777	.25	.83
570	.80	.75	134	.30	39.03	768	.30	.88
561	.85	.80	125	.35	.07	758	.35	.92
553	.90	.84	116	.40	.12	749	.40	.97
544	.95	.89	107	.45	.16	739	.45	41.01
.94536	44.00	36.93	.94098	46.50	39.21	.93730	48.50	41.06
527	.05	.98	089	.55	.26	721	.55	.11
519	.10	37.02	080	.60	.30	711	.60	.15
510	.15	.07	071	.65	.35	702	.65	.20
502	.20	.11	062	.70	.39	692	.70	.24
493	.25	.16	053	.75	.44	683	.75	.29
484	.30	.21	044	.80	.49	679	.80	.34
476	.35	.25	035	.85	.53	664	.85	.38
467	.40	.30	026	.90	.58	655	.90	.43
459	.45	.34	017	.95	.62	645	.95	.47
.94450	44.50	37.39	.94008	47.00	39.67	.93636	49.00	41.52
441	.55	.44	.93999	.05	.72	626	.05	.57
433	.60	.48	990	.10	.76	617	.10	.61
424	.65	.53	980	.15	.81	607	.15	.66
416	.70	.57	971	.20	.85	598	.20	.71
407	.75	.62	962	.25	.90	588	.25	.76
398	.80	.66	953	.30	.95	578	.30	.80
390	.85	.71	944	.35	.99	569	.35	.85
381	.90	.76	934	.40	40.04	559	.40	.90
373	.95	.80	925	.45	.08	550	.45	.94
.94364	45.00	37.84	.93916	47.50	40.13	.93540	49.50	41.99
355	.05	.89	906	.55	.18	530	.55	42.04
346	.10	.93	898	.60	.22	521	.60	.08
338	.15	.98	888	.65	.27	511	.65	.13
329	.20	38.02	879	.70	.32	502	.70	.18
320	.25	.07	870	.75	.37	492	.75	.23
311	.30	.12	861	.80	.41	482	.80	.27
302	.35	.16	852	.85	.46	473	.85	.32
294	.40	.21	842	.90	.51	463	.90	.37
285	.45	.25	833	.95	.55	454	.95	.41
.94276	45.50	38.30						
267	.55	.35						
258	.60	.39						
250	.65	.44						
241	.70	.48						
232	.75	.53						
223	.80	.57						
214	.85	.62						
206	.90	.66						
197	.95	.71						

Determination of Extract.—The extract may be determined directly or, with the aid of a table, from the specific gravity of the dealcoholized beer. The direct method is the more accurate, and is carried out as follows: Into an accurately weighed platinum dish, such as is used in the analysis of milk, weigh 5 grams of beer; evaporate to complete dryness, and multiply the weight of the residue by 20.

Approximately accurate results are obtained by reference to the following table, after Schultze-Ostermann :

BEER EXTRACT TABLE.

Specific gravity.	0	1	2	3	4	5	6	7	8	9
1.011	2.87	2.90	2.92	2.95	2.97	3.00	3.03	3.06	3.08	3.11
2	3.13	3.16	3.18	3.21	3.24	3.26	3.29	3.31	3.34	3.37
3	3.39	3.42	3.44	3.47	3.49	3.52	3.55	3.57	3.60	3.62
4	3.65	3.67	3.70	3.73	3.75	3.78	3.80	3.83	3.86	3.88
5	3.91	3.93	3.96	3.98	4.01	4.04	4.06	4.09	4.11	4.14
6	4.16	4.19	4.21	4.24	4.27	4.29	4.32	4.34	4.37	4.39
7	4.42	4.44	4.47	4.50	4.52	4.55	4.57	4.60	4.62	4.65
8	4.67	4.70	4.73	4.75	4.78	4.80	4.83	4.85	4.88	4.90
9	4.93	4.96	4.98	5.01	5.03	5.06	5.08	5.11	5.13	5.16
1.020	5.19	5.21	5.24	5.26	5.29	5.31	5.34	5.36	5.39	5.41
1	5.44	5.47	5.49	5.52	5.54	5.57	5.59	5.62	5.64	5.67
2	5.69	5.72	5.74	5.77	5.80	5.82	5.85	5.87	5.90	5.92
3	5.95	5.97	6.00	6.02	6.05	6.08	6.10	6.13	6.15	6.18
4	6.20	6.23	6.25	6.28	6.30	6.33	6.35	6.38	6.40	6.43
5	6.45	6.48	6.50	6.53	6.55	6.58	6.61	6.63	6.66	6.68
6	6.71	6.73	6.76	6.78	6.81	6.83	6.86	6.88	6.91	6.93
7	6.96	6.98	7.01	7.03	7.06	7.08	7.11	7.13	7.16	7.18
8	7.21	7.24	7.26	7.29	7.31	7.34	7.36	7.39	7.41	7.44
9	7.46	7.49	7.51	7.54	7.56	7.59	7.61	7.64	7.66	7.69
1.030	7.71	7.74	7.76	7.79	7.81	7.84	7.86	7.89	7.91	7.94
1	7.99	8.01	8.04	8.06	8.09	8.11	8.14	8.16	8.19	8.21

The figures at the head of the several columns represent the fourth decimal place of the specific gravity. Example: Specific gravity, 1.0187; referring to 1.018 in the left-hand column and running out to the column headed by the figure 7, we find 4.85 as the percentage of extract for that gravity.

Detection of Preservatives.—The principal preservative used in beer is salicylic acid; next in importance is fluoride of sodium, which, however, is not used to any considerable extent as yet in this country.

Salicylic Acid.—The ordinary method of extracting by means of ether and testing the residue left on evaporation of the latter with ferric chloride, cannot be used in the examination of beer, since kiln-dried malt contains a principle which gives a reaction identical with that of salicylic acid. The following method, devised by Spica, is, however, satisfactory and reliable: Acidify 100 cc. with sulphuric acid, extract with ether, allow the separated ether to evaporate spontaneously, and warm the residue gently with a drop of strong nitric acid, whereby, if salicylic acid is present, picric acid is formed. The addition of a few drops of ammonia or of sodium hydrate produces the corresponding picrate with its bright-yellow color, which may be imparted to a woollen thread immersed in the liquid.

Fluorides.—Several methods are recommended, and among them the following:

METHOD OF HEFELMANN AND MANN.—Expel the carbonic acid

from 500 cc. of beer, and then add 1 cc. of a solution containing 5 per cent. each of calcium and barium chlorides, and follow it with 0.5 cc. of 20 per cent. acetic acid and 50 cc. of 90 per cent. alcohol. Let stand twenty-four hours and filter. Dry the filter and precipitate collected thereon without washing, and transfer to a platinum crucible. Add strong sulphuric acid, and cover the crucible with a waxed watch-glass with some lines scratched through the wax coating, then heat at 100° C. for two hours, and observe the effect on the exposed glass. This method is said to be of sufficient delicacy to detect the presence of 7 milligrams in a liter.

Brand's Method.—To 100 cc. of beer made slightly alkaline with ammonium carbonate and heated, add 2 or 3 cc. of a 10 per cent. solution of calcium chloride. Boil for a few minutes, filter, and dry the filter and contents. Then proceed as in the method just described. In either process, it is best to place a lump of ice in the concavity of the watch-glass to keep the latter cool; the water should be removed from time to time by means of a pipette so that it may not overflow.

Other Determinations.—Of minor interest are the determinations of acidity and ash.

Total Acidity.—To 10 cc. of beer freed from carbonic acid by shaking, add a few drops of neutral litmus solution, and then add decinormal sodium hydrate until the end reaction is observed. Express the results in parts of acetic acid. One cc. of decinormal sodium hydrate equals 0.006 gram of acetic acid.

Fixed and Volatile Acidity.—Concentrate 10 cc. of beer to a third of its bulk by evaporation, add water up to the original volume, and proceed as above. The difference in results is due to the acetic acid which has been driven off. The fixed acidity is due chiefly to lactic acid, and, if desired, may be so expressed. One cc. of the decinormal solution is equivalent to 0.009 gram of lactic acid. The other acids present include succinic, malic, and tannic.

Ash.—The residue obtained in the direct determination of the extract may be utilized for the estimation of the ash. It should be ignited very cautiously and at as low a temperature as possible until the ash becomes white.

WINES.

Properly speaking, wine is the fermented juice of grapes, though the term is applied also to other products of fermentation of saccharine liquids and fruit juices. It has been in use as a drink from the very earliest periods of civilization. At the present time, wines are produced in infinite variety and of many qualities. The character and properties depend upon a great number of factors, including the variety of the grape, the nature of the soil upon which the vine is cultivated, the climate in general, and the state of the weather in particular when the grapes are ripening, the degree of ripeness when gathered, the method followed in the preparation of the must, and the care with which the other steps in the making of the final product are conducted.

Of very great influence is the extent to which the seeds, skins, and stems of the fruit are allowed to be acted upon. The seeds yield considerable amounts of tannic acid, and the skins lend color, flavor, and to some extent astringency. The most important constituent of the juice of the grape is the sugar, and this is present in greatest abundance when the fruit is fully ripe.

In the making of wine, the first step is the preparation of the must. The grapes, with or without preliminary careful examination and sorting, usually without, are crushed by machinery or by the naked feet of men, so that the juice is set free. Sometimes, the stems are first carefully eliminated, and particularly good individual grapes are cut out and set aside for special use. In the crushing of the fruit, the method of treading has in its favor the fact that the seeds are not thereby affected, and so do not give up so much of their astringent principle. If a white wine is to be made, the must is freed at once from the skins and stalks; but if the product is to be red, these are retained during the process of fermentation. The juice of both the white and the black varieties of grapes is practically without color; but when the dark skins are left in contact with the fermenting mass, the alcohol formed extracts the yellow and blue coloring matters, which become red under the action of the free acids formed at the same time. The constituents of the must are water, sugar, proteid matters, gummy substances, pectous matter, organic acids and their salts, and mineral matters.

The must, with or without the skins and seeds, is fermented in vats of wood, marble, or stone, the process starting very quickly, being induced by organisms which grow on the skin itself. The temperature at which this is allowed to proceed exerts an important influence in determining the character of the wine: conducted between 5° and 15° C., the process is comparatively slow and the aroma of the wine is rich; while at higher temperatures, the rate is more rapid and the bouquet is less marked. The termination of the process is made evident by cessation of the evolution of carbonic acid, the diminution of specific gravity, and the sinking of matters which before had formed part of the scum.

Whether all of the sugar is used up, depends somewhat upon the amount of proteid nutrient material for the growth of the organisms by which the conversion is carried on. If this is exhausted first, there will be a residue of sugar, and the product will be correspondingly sweet; if there is an abundance of proteid matter, the sugar will be the first to be exhausted, and the wine will be "dry." It is sometimes necessary to add nitrogenous matter, such as egg albumin or gelatin, in order to keep the process from ceasing too early.

As the percentage of alcohol in the fermenting must rises, the bitartrate of potassium present is deposited gradually, owing to its insolubility in alcohol. The deposit is known commercially as argol, and is the source of cream of tartar.

When the first fermentation is completed, the alcoholic liquid is drawn

off into casks, in which it is kept for a number of months, the vessels being kept constantly filled. It now undergoes a second slow fermentation, which brings about changes which are not understood excepting in their gross result, which is the production of the "bouquet" or flavor. In this second process, there occur a farther deposition of argol and an oxidation of aldehyde to acetic acid. The bouquet is due to a combination of ethers, the chief of which is œnanthic ether, supposed to be produced from the alcohol through the agency of the organic acids normally present.

The wine next is racked off into other casks, and in some cases it is necessary to do this several times. Sometimes, the appearance of the wine is such that "fining" is necessary. This consists in the addition of egg albumin, isinglass, or other gelatinous matter, which in its descent attracts and enmeshes the fine particles of matter which not only prevent brilliancy, but later on may impair the keeping quality of the wine.

Classification of Wines.—Wines are classified variously according to color, strength, sweetness, and content of carbonic acid. According to color, they are classed as red or white, the latter term applying not only to the very light, almost colorless kinds, but also to those having a decided yellowish or even yellowish-brown color, such as is possessed by "white port." The red wines include those generally known as Clarets and Burgundies, though both these kinds exist in the white forms. The white wines include the white Clarets commonly designated as Sauternes, white Burgundies of which Chablis is a type, the Rhine and Moselle wines, and others.

According to strength, wines are classed as natural and fortified. The natural wines contain of alcohol only that which is formed in the process of natural fermentation; the fortified wines, such as Sherry, Port, and Madeira, contain, besides, a considerable amount in the form of added spirits.

According to their content of sugar, wines are classed as sweet or dry. Some of the sweet wines contain added sugar and that which has escaped the action of the yeast plant. In the dry wines, all or nearly all of the sugar has been converted into alcohol. Not all of the sugar, however, in any wine is converted into alcohol and carbonic acid, small amounts going to form glycerin and succinic acid.

According to their content of carbonic acid, wines are classed as still or sparkling (effervescent). The natural wines contain practically no carbonic acid; the sparkling, or effervescent, wines, as Champagne and sparkling Moselle, are in a sense artificial in that they are subjected to a process of fermentation in the bottle, sugar being added for the purpose. They are flavored also with liqueurs.

Composition of Wines.—**Alcohol.**—The most important constituent, the active principle, of wine is ethylic alcohol. The higher alcohols, propylic, butylic, and amylic, are always present in traces. The amount of alcohol is variable, ranging in natural wines from 6 to 14 per cent. by weight, but ordinarily present between the limits of

9 and 12 per cent. In fortified wines, the amount ranges from 12 to about 22 per cent., but is usually about 17 per cent.

Sugar.—While the amount of sugar in the original must ranges between 12 and 33 per cent., in the natural finished product it is as a rule quite low, ordinarily considerably under 0.5 per cent., and often none at all. The sweet Tokays contain exceedingly variable amounts, ranging from 3 to 26 per cent., Ports and Madeiras about 4, and Sherries somewhat less; but American Ports, Sherries, and Madeiras are commonly fairly rich in sugar. Domestic Champagnes, also, contain notable amounts, but those of foreign origin, even those ordinarily classed as sweet, contain but small amounts, the impression of sweetness being largely due to the flavorings of the liqueurs added. Four specimens analyzed by the author, one of which (No. 4) is well known as an extra sweet wine, yielded the following results :

Brand.	Sugar.	Extract.	Alcohol by weight.
1. Brut Imperial (Moët & Chandon)	1.35	3.27	11.15
2. St. Marceaux	1.52	3.21	10.38
3. Dry Imperial (Moët & Chandon)	1.56	3.18	10.85
4. White Seal (Moët & Chandon)	4.76	6.88	10.23

Extract.—The extract, or residue, represents the sum of the non-volatile constituents, including sugar, nitrogenous matters, tartaric and other acids, mineral and organic salts, coloring and astringent principles, glycerin, etc., all of which are present in but small quantities. In sweet wines, the principal constituent of the residue is sugar. The actual food value of the residue is, apart from the sugar, practically *nil.*

Adulteration of Wines.—Wines have been subject to a wide variety of adulterations from the earliest times, and measures against the practice of their sophistication were enforced long before those against the adulteration of bread and other foods were thought of. The ancient Greeks and Romans, for example, enacted stringent laws and appointed officials whose duty was to detect and punish those who offended.

At the present time, adulteration of wines is practised very extensively, and includes the addition of water, of coloring agents, of preservatives, of glycerin to impart sweetness and body, of alum to heighten color and of decolorizing agents to remove it, the substitution of wholly artificial compounds, and processes for the "improvement" of the natural product. The flavoring and coloring agents are as a rule quite harmless. They are employed chiefly in the manufacture of factitious wines, and not uncommonly the same agent serves in both capacities. Prunes, raisins, dried apples and peaches, and dates are commonly so employed. Various berries, logwood, alkanet, red beets, coal-tar products, and a wide variety of other substances are said to be used for imparting color.

The addition of alcohol is recognized as a legitimate practice in the case of the fortified wines; that of glycerin has no sanitary significance. The amount of alum used for heightening color is so small as to be productive of no harm. The employment of decolorizing agents is, like the substitution of artificial products, a fraud pure and simple; but the use of preservatives, such as salicylic acid, formaldehyde, and sulphites, is objectionable on account of danger to health.

For the improvement of wines, a number of processes are in vogue. Chief of these is "plastering," which consists in the addition of gypsum to the must for the purpose of securing a more brilliant appearance and increasing the keeping qualities. This agent decomposes the potassium bitartrate, forming tartrate of calcium and acid sulphate of potassium, which latter eventually is converted into the neutral sulphate. Chaptalizing consists in the neutralization of the acidity of the must by the use of marble dust, and the addition of cane sugar or glucose. This process diminishes the natural acidity and increases the yield of alcohol. Gallizing consists in diluting the must so as to reduce its acidity to a given standard, and adding a sufficient amount of cane sugar or glucose to insure the production of the proper alcoholic strength.

The Pasteur treatment of wines is resorted to sometimes as soon as evidence of untoward fermentations producing the so-called "wine diseases" appears. The wine, best in the bottle, is heated to from 55° to 65° C. according as the alcoholic strength is high or low, whereby the existing germs are killed and the preservation of the wine is made permanent.

The manufacture of artificial wines is carried on extensively in this country and abroad, in spite of the fact that fair grades of the genuine product are obtainable at very low prices. A number of hand-books and guides to the "art of blending and compounding" are published for the use of wholesalers and retailers of wines and liquors, and from several of these the following are selected as examples of the methods given: (1) Port: cider, 30 gallons; alcohol, 5 gallons; syrup, 4 gallons; kino, ½ pound; tartaric acid, ¼ pound; port wine flavor, 6 ounces. (2) Claret: California hock, 40 gallons; extract of kino, 8 ounces; essence of malvey flower, 8 ounces. (3) Sherry: equal parts of Spanish sherry and California hock. (4) White wine: dissolve 25 pounds of grape sugar and 1 of tartaric acid in 25 quarts of hot water, add 75 quarts of cold water and 50 pounds of grape pulp, stir, cover, let ferment for four or five days, and strain.

In France, an artificial substitute for wine, known as "piquette," is manufactured very extensively from raisins and dried apples. It is estimated that in 1898 no less than 50,000,000 gallons were made and consumed. The process is exceedingly simple. To each gallon of water used are added 1 pound of raisins and 1 of dried apples; the mixture is placed in an open vessel and allowed to stand three days. It is then bottled with ½ teaspoonful of sugar and a small piece of cinnamon in each bottle. It is said to be a pleasant and harmless beverage.

Analysis of Wines.

Determination of Alcohol.—The process for the determination of alcohol is the same as that followed in the analysis of beer, except that the distillation or evaporation is carried farther. At least 60, or better 75 cc., are collected by distillation or driven off by open evaporation.

Determination of Extract.—The specific gravity of the de-alcoholized wine gives, as with beer, an approximate estimate of the amount of extract, and the same table may be used. The direct determination is made by evaporating 50 cc. of the wine in a weighed platinum dish on a water-bath and drying to constant weight in an air-bath. With sweet wines, a smaller amount is preferable.

Determination of Acidity.—The total acidity, due to bitartrate of potassium, tartaric, malic, and other acids, is reckoned as tartaric acid. Twenty-five cc. of the wine are titrated in the usual way with decinormal sodium hydrate, 1 cc. of which equals 0.0075 gram of tartaric acid.

The volatile acids are reckoned as acetic acid. Fifty cc. of the wine are placed in a distilling flask connected by means of its outlet tube with a Liebig condenser, and, by means of a bent tube passing through its stopper and projecting well below the surface of the wine, with a flask containing 250 cc. of water. The contents of both flasks are brought to the boiling-point, and then the flame beneath the wine is turned down and the current of steam passed through until 200 cc. of distillate are collected. This is titrated with decinormal sodium hydrate, and the result is expressed as acetic acid. The determination of the amounts of the individual acids is of no hygienic interest.

Determination of Sugar.—The amount of sugar in wine is determined by reduction of Fehling's solution, by the method of Allihn, and by polariscopy. For the details of these methods, the reader is referred to any of the standard works on wine analysis, for the small amount of sugar ordinarily present is of but little hygienic interest, and the description of the processes would require an amount of space vastly out of proportion to the importance of the subject.

Determination of Ash.—The residue obtained in the determination of extract can be utilized for the determination of the ash. It should be ignited at as low a temperature as possible.

Detection of Coal-tar Colors.—While the presence of coal-tar colors is not difficult of detection, the identification of the individual members of the group is by no means easy. The following tests give reliable indications of the presence of this class of colors. Equal volumes of wine and ether, agitated in a flask, and let stand and separate, will show in the ether layer a red coloration, if anilin colors are present. In place of ether, nitro-benzene may be used; this removes fuchsin, eosin, and methylen-blue, but does not take up any of the vegetable colors, safranin, or indigo-carmine. Amyl alcohol, also, will become reddened when agitated with wine containing anilins, but the

wine must first be made slightly alkaline. If white woollen threads are immersed for some time in the colored liquids, they will take up the colors and become dyed.

Cazeneuve's test is performed as follows: To 10 cc. of wine add 0.20 gram of mercuric oxide, then shake for one minute, boil, let stand, and filter. The filtrate should be clear, and in the absence of anilins should be colorless; if it is red, an anilin color is present. Absence of color is, however, not conclusive evidence of purity, since a number of the anilin colors, as eosin, methylen-blue, and others, are wholly precipitated, and so do not appear in the filtrate Safranin, methyl-eosin, Ponceau red, and a number of other colors are precipitated partially or completely.

A number of these, including safranin, Bordeaux red, and Ponceau red, may be separated by the following process: To 200 cc. of wine from which the alcohol has been expelled, add 4 cc. of 10 per cent. hydrochloric acid and some white woollen threads, and boil for five minutes. Withdraw the threads and wash them with cold water acidulated with hydrochloric acid, next with hot water similarly acidulated, and lastly with distilled water alone. Boil the threads in 50 cc. of distilled water containing 2 cc. of strong ammonia water, remove them, and immerse new ones. Make acid with hydrochloric acid and boil for five minutes. Varying shades of rose-red will be imparted to the threads if any of these colors are present.

Fuchsin may be detected by the following methods: (1) To 100 cc. of wine add 5 cc. of ammonia water and 30 cc. of ether, and shake. Remove the ether, which will have no color, place it in a watch-glass with a white woollen thread, and let it evaporate to dryness. If even a trace of fuchsin is present, the thread will show a distinct rose-coloration. (2) Mix 2 volumes of wine and 1 of solution of basic acetate of lead, warm gently, and shake. Filter, add to the filtrate a small amount of amyl alcohol, shake again, and remove the amyl alcohol. If this has a red color, it may be due to fuchsin or to orseille. To a portion of the colored liquid add hydrochloric acid; if the color is discharged, it was due to fuchsin. To another portion add ammonia water; if the color is changed to purple violet, it was due to orseille,

Detection of Preservatives.—**Salicylic Acid.**—Spica's method for detecting salicylic acid in wine is as follows: Acidify 10 cc. of wine with a few drops of hydrochloric acid, and shake with an equal volume of ether. Remove the ether, filter it if necessary, and evaporate to dryness. Add a drop of nitric acid, warm gently, and add an excess of ammonia and 1 cc. of water. Immerse a white woollen thread, apply gentle heat, and then withdraw the thread, wash it, and dry it between pieces of blotting-paper. A yellow color indicates that salicylic acid was present in the wine.

Another method, for which great delicacy is claimed, even to a tenth of a milligram in a liter, is the following: Acidify 50 cc. of wine, beer, or other liquid with sulphuric acid, and shake it with an equal volume of a mixture of equal parts of ether and naphtha. Separate

the ether, filter, and evaporate down to 5 cc.; then add 3 cc. of water and a few drops of very dilute solution of ferric chloride, and filter through a wet filter. In the presence of salicylic acid, the watery portion will have a violet color. A modification of this method consists in extracting with ether alone, and then extracting the ether residue with naphtha; the residue on evaporation of the naphtha is treated with water and very dilute ferric chloride.

Formaldehyde.—To 10 cc. of wine, add a few drops of milk known to be free from formaldehyde, and shake in a test-tube. Next pour down the side of the tube about 4–5 cc. of strong commercial sulphuric acid, and note the color at the line of contact of the two liquids. (See under Milk.)

Sulphites.—To 200 cc. of wine (or beer) add 5 cc. of phosphoric acid; distil 100 cc., using a Liebig condenser with a bent delivery tube which dips below the surface of 20 cc. of decinormal solution of iodine. By distilling in a current of washed CO_2, the danger of back suction is avoided. The reaction which is brought about is as follows: $SO_2 + 2H_2O + I_2 = H_2SO_4 + 2HI$. The amount of SO_2 may be determined by estimating the excess of iodine by means of standard sodium thiosulphate, or the distillate may be acidified with hydrochloric acid and the contained sulphuric acid precipitated as barium sulphate by the addition of barium chloride. One milligram of barium sulphate is equivalent to 0.2748 milligram of SO_2.

CIDER.

Cider, or apple wine, is the fermented juice of the apple. It is made very extensively wherever apples are grown, and is a very important product, viewed either as a beverage or as the basis of what is regarded generally as the best kind of vinegar.

A very large, if not the greater, part of the cider produced is made without special care by a very simple process. The apples used are ordinarily those not marketable on account of small size, greenness, over-ripeness, or bruises; but often perfect fruit is used when the crop is so abundant that there is more profit in converting it into cider and vinegar than in sending it in barrels to market. The fruit is ground to a pulp and pressed, and the juice is drawn into barrels and allowed to ferment. If the same amount of care is taken as is given to the making of wine from grapes, the product is of a superior grade, and keeps very well; but as ordinarily made in the country, its life is short, unless treated with salicylic acid or other preservative to check fermentation. In France, where the yearly yield is very great, the best grades are made with due regard to the temperature at which the fermentation proceeds, and to the importance of racking off and fining.

Cider of good quality contains usually from 3 to 5 per cent. and sometimes as much as 8 per cent. by weight of alcohol. Very new sweet cider may contain less than 1 per cent. The total extract, which is largely sugar, is in inverse proportion to the amount of alcohol; in

average samples, it amounts to from 4 to 6 per cent., while in new sweet cider it is commonly nearer 9 per cent. The free acids, chiefly malic, amount to less than 0.75 per cent., and average about 0.40.

The adulterants of cider are water and salicylic acid. The latter is found very commonly in that which reaches the city markets.

PERRY.

Perry, or "pear cider," is the fermented juice of pears. It is made in the same way as cider. Pear juice being richer in sugar than apple juice, it follows that the average content of alcohol is somewhat higher than in cider.

Distilled Alcoholic Beverages.

Spirits, or distilled liquors, are the product of distillation of fermented sugar solutions. Their most important constituent is ethylic alcohol, which is ordinarily present to the extent of about 45 per cent. When freshly made, they contain variable small quantities of higher alcohols, furfurol, fatty acids, and other volatile principles, which together constitute what is known as fusel oil, the chief constituent of which is amylic alcohol.

Each kind of grain or other raw material from which the fermentable sugar solution is obtained yields a different kind of fusel oil; different because of the changing relative proportions of its constituents, which include butylic, propylic, and amylic alcohols, and their corresponding acids, butyric, propionic, and valerianic, and other matters. That which is found in potato spirits is richest in amylic alcohol, and is the most toxic, while that from grapes contains by far the least and produces the least harm. During the process of aging, the constituents of the fusel oil undergo chemical changes which result in the formation of œnanthic, acetic, and butyric ethers, acetate and valerianate of amyl, and other compounds, which together constitute the aroma or "bouquet." Thus, a spirit is improved in two ways by long storage: it loses in toxicity and gains in flavor.

The relative toxicity of the several alcohols and of other constituents of fusel oil has been determined by Dujardin-Beaumetz and others, who show that the poisonous properties increase with the boiling-point and molecular weight. Jeffroy and Serveaux[1] determined the amounts in grams necessary per kilogram to kill a rabbit, as follows: ethylic alcohol, 11.70; propylic alcohol, 3.40; butylic alcohol, 1.45; amylic alcohol, 0.63; furfurol, 0.24. Daremberg[2] found by experiment that artificial spirits and wines made with pure rectified alcohol are less toxic than the genuine products, by reason of the absence of the constituents of fusel oil. Roubinowitch,[3] speaking of the greater toxicity of the higher alcohols, calls attention to the fact that the distillates from cider, perry, and fermented grains, potatoes, and molasses, are much more toxic than brandy.

[1] Archives de Médecine expérimentale et d'Anatomie pathologique, 1895, p. 569.
[2] Ibidem, p. 719.
[3] Gazette des Hôpitaux, 1895, p. 237.

Most spirits are colored artificially by the addition of harmless coloring agents, the most widely used of which is caramel. As the practice of coloring is in response to the demand of the consumer for a darker color than can be obtained otherwise, it can hardly be regarded as an adulteration.

BRANDY.

Brandy is obtained by distilling wines of the poorer qualities, often mixed with the "lees," or dregs from the wine casks, and the "marc," or solid refuse left after pressing the grapes. The lees and marc are used also alone for the production of a highly odorous brandy, which is much used for improving the flavor of other brandies, and for giving flavor to the artificial brandies made from pure alcohol and water. From this marc brandy is obtained the oily substance, œnanthic ether, which is known commercially as "oil of wine."

Brandy is produced very largely in France, and much less extensively in Spain, Portugal, and Germany; in California and in the wine-growing region of the Ohio and Mississippi Valley, it is produced in large quantities and of most excellent quality.

The colorless distillate is stored for some time in oaken casks, from which a small trace of tannin and a varying depth of amber color are acquired. The flavor, which in general depends upon the kind of grapes, their condition when pressed, and the care observed in the making of the wine, becomes improved during storage. The liquor is then colored and bottled for the market.

Good brandy should contain from 39 to 47 per cent. of alcohol by weight, should have an agreeable odor and taste, and should be free from substances added to impart sharp taste and apparent strength. The nearly dry residue from 100 cc. very slowly evaporated on a water-bath should have a pleasant odor, and its taste should be neither sweet nor sharp; a sharp odor points to the presence of fusel oil derived from potato or cereals; a sweet taste is indicative of added sugar or glycerin; and a sharp taste is suggestive of cayenne or other spice.

Much of the brandy of commerce is a purely artificial product made from alcohol or potato spirits, water, and flavorings. The formulæ for making brandy are very numerous, and not a few require what is known as brandy essence, an article made with ethers and other substances in varying proportions. By one formula, it is made with 5 parts of œnanthic ether, 4 of acetic ether, 3 of tincture of galls, 1 of tincture of pimenta, and 100 of alcohol; by another, it consists of 15 parts of acetic ether, 12 of sweet spirit of nitre, and 1 of rectified wood spirit. One part of either of these mixtures is sufficient to flavor a mixture of 1000 parts of alcohol and 600 of water.

As examples of the way in which factitious brandy is made, the following will serve: (1) Boil 5 ounces of raisins and 6 of St. John's bread in water, filter, and make up to 10 quarts; mix this with 20 quarts of alcohol, 10 ounces of brandy essence, and $\frac{1}{2}$ ounce of essence of violet flowers. (2) Dissolve 1 pound of argols and 3 of sugar in a

gallon of water, add 40 gallons of alcohol, $\frac{1}{4}$ pound of acetic ether, 2 ounces of tincture of kino, 6 pounds of bruised raisins, and a sufficient amount of caramel, and let stand for fourteen days; strain and bottle.

WHISKEY.

Whiskey is the product of distillation of the fermented mash of grain or potatoes. The raw materials from which the mash is made include malt, wheat, rye, corn, oats, and potato. In the process of mashing, the starch of the grain is changed to sugar by the diastase of the malt; and since this ferment is capable of converting other starch than that with which it is associated, it is customary to mix malt and raw grain in the proportion of 1 to from 5 to 9 parts. A bushel of grain makes about 2.5 gallons of spirits. In this country, the grains employed are chiefly corn, wheat, and rye; in Great Britain, barley, oats, and rye are used together; potatoes are used to a greater or less extent on the continent. The mash for Scotch whiskey is very commonly prepared from 2 parts of malt, 7 of barley, and 1 each of oats and rye; that for Irish whiskey is the same, with the exception of the rye.

As soon as the fermentation of the mash through the agency of yeast is complete, the distillation is begun. The first distillate, known as "low wine," is re-distilled. The second distillate is stronger and less rich in fusel oil, which, being less volatile than ethylic alcohol, comes over chiefly in the later portions. The new whiskey is stored for several years, in order that it may acquire the flavor due to the formation of new compounds from the constituents of the fusel oil. During storage, it takes up a trace of tannin from the oak of the casks.

The flavor of whiskey depends upon the nature of the raw material, and largely upon the aging process. The disagreeable flavor and odor of new whiskey are due to fusel oil; the smoky taste of Scotch and Irish whiskies is due to the smoke of the peat and turf fires over which the malt is dried. Indian corn whisky has a much different flavor from that of rye whiskey; this flavor is regarded highly by many to whom rye whiskey is unpalatable and insipid, and at the same time it is so full that to others it is rank and nauseating. The peculiar flavor of Bourbon whiskey, so-called because originally produced in Bourbon County, Kentucky, is due to the corn from which, with rye, the mash is prepared.

Whiskey of good quality should contain about 45 per cent. of alcohol by weight, and should yield not more than 0.25 per cent. of residue, which should have a slightly aromatic odor and but little taste.

Whiskey is manufactured very largely from alcohol, water, and various flavoring compounds, some of which can hardly be looked upon as wholly innocuous. The following directions are taken from a small work, the object of which is, according to the preface, "to give the dispenser of liquors thorough and practical information by which he will be enabled to compound, and blend liquors for his own purposes, and thus secure the additional profit."

1. *Bourbon Oil.*—Take of fusel oil, 64 ounces; acetate of potassium and sulphuric acid, each, 4 ounces; and black oxide of manganese, 1 ounce. Dissolve ½ ounce each of sulphate of copper and oxalate of ammonium in 4 ounces of water, mix all in a glass percolator, and let rest for twelve hours. Then percolate and put into a glass still, and distil 64 ounces.

2. *Rye Oil.*—Mix 64 ounces of fusel oil, 8 each of œnanthic ether, chloroform, and sulphuric acid, and 2 of chlorate of potassium in 8 of water, place in a glass still, and distil 64 ounces.

3. *Beading Oil.*—Mix together 48 ounces of oil of sweet almonds and 12 of sulphuric acid, and when cool neutralize with ammonia and dilute with double the volume of proof spirit. "This is used to put an artificial bead on inferior liquors." For making the lowest grade of whiskey, one is directed to mix 32 gallons of alcohol and 16 of water, 4 ounces of caramel and 1 of beading oil. By adding oil of rye or oil of Bourbon, "making the result rye whiskey or Bourbon, as the case may be," the value is said to be increased.

From another similar source the following recipes for factitious whiskey are taken:

1. *Bourbon Whiskey*—Proof spirit,[1] 100 gallons; pear oil, 4 ounces; pelargonic ether, 2 ounces; oil of wintergreen, 13 drachms in ether; wine vinegar, 1 gallon; caramel color, a sufficient quantity.

2. *Old Bourbon.*—Alcohol, 40 gallons; Bourbon whiskey, 5 gallons; sweet spirit of nitre, 2 ounces; fusel oil, 2 ounces. Mix and let stand four days.

3. *Old Rye.*—Soak a half peck of roasted dried peaches, put them into a woollen bag and leach with common whiskey sufficient for a barrel, and add 12 drops of strong ammonia.

4. *Scotch Whiskey.*—Alcohol, 46 gallons; genuine Scotch, 8 gallons; water, 18 gallons; ale, 1 gallon; creasote, 5 drops in 2 ounces of acetic acid; pelargonic ether, 1 ounce; honey, 3 pounds.

5. *Irish Whiskey.*—Same as above, substituting Irish for Scotch, and omitting the honey.

RUM.

Rum is made by distilling fermented molasses or the skimmings of sugar boilers, with, not uncommonly, other substances, as pineapples and guavas, to give flavor. The characteristic flavor of rum is due to butyric ether. The alcoholic content of rum is very variable, ranging from 30 to over 60 per cent. by weight. Like other spirits, rum is very largely an artificial product of alcohol, water, and flavorings

[1] Proof spirit is defined by an act of Parliament as a diluted spirit which at 51° F. shall weigh exactly twelve-thirteenths as much as an equal measure of distilled water. It contains half its volume of alcohol of sp. gr. 0.7939 at 60° F., or 49.5 per cent. by weight, or 57.27 per cent. by volume of absolute alcohol. Its sp. gr. is 0.91984. Over and under proof mean that a spirit is stronger or weaker than proof spirit, and the excess or deficiency is expressed as so many degrees over or under proof. The expression, for example, 25 under proof, means that the specimen consists of 25 parts of water and 75 of proof spirit; 25 over proof means that 100 parts may be diluted with 25 of water to bring it to the strength of proof spirit.

known as rum essence. One of these consists of 15 parts of butyric ether, 2 each of acetic ether, essence of vanilla, and essence of violet, and 90 of alcohol. Another consists of 32 parts each of rum ether and acetic ether, 8 of butyric ether, 16 of extract of saffron, and $\frac{1}{8}$ of oil of birch cut in strong alcohol. The rum ether required is a product of the distillation of alcohol, sulphuric acid, pyroligneous acid, and black oxide of manganese. Prune juice is also a common addition to factitious rum for its flavor and color.

GIN.

Gin is an alcoholic liquor flavored with juniper berries and a great variety of other substances, including cardamom, coriander, cassia buds, calamus, orris, angelica root, orange peel, licorice powder, and sugar. It should contain about 40 per cent. of alcohol, and not over 6 per cent. of total residue, including sugar.

Liqueurs.

Liqueurs, or cordials, are manufactured compounds of alcohol, essential oils, cane sugar, and coloring matter. They contain usually about 40 per cent. of alcohol by weight, and from 25 to 50 per cent. of cane sugar. The colorings are, as a rule, of vegetable origin, but sometimes the coal-tar colors are employed. Even in the small amounts ordinarily taken, their use can hardly be advised, in view of the adverse report (March 10, 1903) of the Committee of the Académie de Médecine, to whom the question of their wholesomeness was referred by the French government. The essential oils are the objectionable ingredients, apart from the alcohol. Especially deleterious is one which is taken commonly with considerable water before meals, namely, absinthe. By some the poisonous constituent is held to be the oil of wormwood (*Artemisia absinthium*), by others the oil of star anise (*Illicium*), both of which it contains. To which constituent the blame belongs is of no great consequence, the drink being one which should be shunned above all others as a poison, without regard to the innocuousness of most of its constituents; but it is unlikely that its disastrous effects are due to wormwood, which as a drug has little or no action, and which enters into the composition of another drink, vermuth, which enjoys a good reputation, but is not a cordial. It is a fortified white wine in which certain herbs and other vegetable matters have been infused. The ordinary French vermuth is made from wormwood, bitter-orange peel, water germander, orris root, chamomile, Peruvian bark, aloes, cinnamon, nutmeg, centaury, and raspberry, but many other substances are used by different makers. The fresh product has a very pronounced flavor, which is mellowed by age. The wines most used in making French vermuth are from the Rhone Valley, Picpoul, and from the southernmost parts of France. Italian vermuth differs materially from the French; it is a much

weaker infusion with a far more bitter taste. The materials used are in the main the same, but they are employed in very different proportions. Vermuth contains about 17 per cent. of alcohol.

Section 6. CONDIMENTS, SPICES, AND BAKERS' CHEMICALS.

The condiments include a large number of food accessories which, while they are themselves of no nutritive value in the amounts which it is possible to eat, serve a very useful purpose in imparting flavor, and in stimulating appetite and digestion. Among them are some which act through free acids, some through volatile oils, some through resinous matters, and one, perhaps the most important of all, common salt, through itself alone. Some are simple substances; as vinegar, salt, and the spices; while others are combinations of a number of ingredients blended according to definite and, as a rule, secret formulas; as sauces, chutneys, catsups, and curries. Only when these compounded articles contain substances injurious to health can they be regarded as adulterated. The tomato catsups are preserved very commonly with salicylic acid or other preservatives, and colored with anilin dyes. Thus, of 25 samples of different makes examined in 1897 by the health authorities of San Francisco, 20 contained salicylic acid, 2 contained this agent together with borax, and 1 contained formaldehyde; 16 were artificially colored, mostly with coal-tar colors. Of 39 examined by the Massachusetts State Board of Health during 1899, 15 contained salicylic acid and 13 benzoic acid.

VINEGAR.

Vinegar is a weak solution of acetic acid resulting from the acetous fermentation of saccharine solutions which have undergone alcoholic fermentation. It contains, in addition to acetic acid, small and unimportant amounts of alcohol and aldehyde, and extractive matters in varying amounts, according to the nature of the original liquid. The acetic acid contained is the product of oxidation of alcohol through the agency of *Mycoderma aceti*, a fungus which forms what is known as the "mother of vinegar." Thus, the change from sugar to acetic acid involves two separate fermentative changes through the agency of two different organisms, *Saccharomyces cerevisiæ* and *Mycoderma aceti*.

There are several kinds of vinegar in common use, as follows:

Cider Vinegar.—In this country, cider vinegar is regarded very generally as the most desirable kind. It contains no aldehyde, about 4.50 to 5.50 per cent. of acetic acid, marked traces of malic acid, and about 2 per cent. of total residue, or "cider-vinegar solids."

Wine Vinegar.—In wine-producing countries, the vinegar in common use is made from the cheaper kinds of wine. It has color or not, according to the kind of wine from which it is made. The so-called white wine vinegar in common use in this country among the foreign-

born population is a colorless product of the oxidation of dilute spirits. Wine vinegar contains rather more acetic acid than cider vinegar, but far less residue.

Malt Vinegar.—In England, which is neither a cider-producing nor a wine-producing country, the vinegar in commonest use is made from a wort prepared from malt and unmalted grain. It is less strong in acetic acid than the vinegars already described, but commonly contains sulphuric acid, which, under the English law, is a permissible admixture to the extent of not exceeding 0.10 per cent.

Molasses Vinegar.—A very large part of the domestic supply of vinegar is manufactured from fermented molasses. It is made to imitate cider vinegar in color, and is sold commonly under the name of that article. It yields about the same amount of acid, but is very deficient in residue. The latter has a very bitter taste, and after complete ignition yields an ash containing no potassium salts, while that from cider vinegar gives a decided indication.

Spirit Vinegar.—Spirit vinegar, also known as "Quick Process" vinegar, is made from diluted alcohol. The process used is the same as that employed in the making of malt vinegar and molasses vinegar. A series of suitable vats is constructed and filled with beech or birch shavings or twigs, which by appropriate treatment become coated with *Mycoderma aceti.* The alcoholic liquid is allowed to percolate through, and in its passage the alcohol is transformed. The temperature of the room is maintained at about 70° F.

Adulterations of Vinegar.—The principal adulterations of vinegar are the addition of water and the coloring of inferior grades so that they may be sold as cider vinegar. Where laws are in force establishing standards of acidity and residue for cider vinegar, a very common fraud is the addition of cider jelly or of a preparation made from apple pomace to a cheap vinegar of the proper strength, colored, if necessary, with caramel. Such compounds always show but slight or no reaction when tested for malic acid. The addition of mineral acids is not a common practice in this country.

Examination of Vinegar.—**Acidity.**—To 6 cc. of the specimen in a porcelain casserole, add a few drops of phenolphthalein solution and about 20 cc. of distilled water. Titrate with decinormal sodium hydrate solution, adding little by little until the appearance of a faint pink coloration. The number of cc. of the reagent used, divided by 10, equals the percentage of absolute acetic acid.

Residue.—Evaporate 5 grams in an accurately weighed platinum dish to complete dryness over boiling water. After the residue is weighed, it may be ignited for its yield of ash.

Genuine cider vinegar should give no more than a faint cloudiness on being tested with nitrate of silver and chloride of barium (absence of more than traces of chlorides and sulphates), and should yield a fairly copious precipitate with solution of subacetate of lead (presence of malic acid). The residue should not taste bitter (absence of caramel). Cider vinegar to which water has been added is likely, according to

the nature of the water, to show more than the usual results on testing for chlorides and sulphates, and to yield notable traces of lime. Molasses vinegar generally yields marked indications of lime salts and a more or less pronounced odor of rum.

LEMON JUICE AND LIME JUICE.

Lemon juice is the expressed juice of the ripe fruit of *Citrus limonum*. It is a somewhat turbid yellowish liquid, with a very acid taste and a slight agreeable odor, due in part to the presence of a small trace of volatile oil from the rind. It should contain about 7 to 10 per cent. of citric acid, and should yield from 0.50 to 1.00 per cent. of ash. Its specific gravity should be not less than 1.030, and is usually above 1.040. As it is quick to undergo decomposition in its natural condition, a number of methods have been proposed for its preservation, the best of which appears to be, first to clarify it by means of strong alcohol, next to filter or decant from the precipitated matters, and then to expel the alcohol by heat. The clear juice may then be bottled and sterilized.

Lime juice is the expressed juice of the sour lime, *Citrus acida*, and of the sweet lime, *C. limetta*. It contains usually somewhat less acid than lemon juice, and has a lower specific gravity. It is preserved by the same method.

As antiscorbutics, lemon juice and lime juice are of about equal value, and far superior to vinegar.

Adulteration.—Lemon juice is much more subject to adulteration than lime juice, but both are falsified and imitated extensively. In fact, it would not be overstating the case to say that by far the larger part of the lemon juice sold in this country is wholly factitious. Commonly, it is nothing more than an aqueous solution of citric acid; sometimes, it is flavored with oil of lemon. Its taste is much sharper and less agreeable than that of the genuine article. The residue is very different in character and appearance, and leaves practically no ash on ignition. Other acids are used sometimes in place of or in addition to citric acid. The one most commonly employed is said to be tartaric; this is detected readily by the gradual formation of bitartrate of potassium on addition of the acetate. The mineral acids are said to be added not infrequently; they are detected without difficulty by the common tests.

SALT.

The best grades of common salt are white, dry, free from dirt, and completely soluble in water. Many specimens of good quality contain traces of chloride of magnesium, which causes caking. In humid weather, even the best grade of salt absorbs moisture sufficient in amount to cause it to lose its dry, powdery nature. The addition of about 10 per cent. of corn starch serves to keep it dry and powdered.

MUSTARD.

Mustard is the flour of the seed of the black and the white mustard, *Sinapis niger* and *S. alba*. The first mentioned is much the more pungent of the two; on being wet with water, a volatile oil is developed from two of its constituents. The white mustard yields no volatile oil by this treatment, but develops an acrid principle. Both varieties of seeds contain a bland fixed oil to the extent of 20–25 per cent. As this adds nothing to the flavor, makes grinding more difficult, and exerts an injurious influence on the keeping qualities, it is removed from the whole seeds by pressure.

Mustard is largely subject to adulteration with wheat, rice, and corn flour, with the farther addition of turmeric to restore the color lost by dilution. These substances are detected very easily by means of the microscope. Furthermore, since starch is wholly absent from pure mustard flour, if a small portion of a suspected sample, boiled in a little water in a test-tube and cooled, gives a blue or bluish-black color on the addition of compound iodine solution, it unquestionably is adulterated.

PEPPER.

Pepper is the fruit of *Piper nigrum*, a perennial climbing shrub. The unripe berries, dried for several days after being picked, are known as Black Pepper. The ripened berries, dried and decorticated, are known as White Pepper. In the powdered form, in which they are retailed most commonly, both are adulterated very extensively with substances of a harmless nature. These include ground shipbread, cornmeal, cocoanut shells, rice, buckwheat, oatmeal, mustard hulls, charcoal, olive stones, and a variety of other substances of little or no value, capable of being reduced to powder.

The simplest method of determining the purity of this or any other form of spice is to reduce a specimen of the genuine unground substance to powdered form and study its appearance under the microscope, and then to compare it with the sample in question. Each kind has its characteristic appearance, and so with a little practice one is enabled to determine very quickly the question of purity. By a similar study of the microscopic appearances of the common adulterants, these may readily be identified in the mixture. The chemical analysis is intricate and tedious, and not always conclusive.

CLOVES.

Cloves are the flower buds of *Eugenia caryophyllata*, picked while red and dried in the sun. They contain about 16 per cent. of volatile oil, easily removed and of considerable value. In the powdered form, cloves are adulterated commonly with allspice, clove stems, spent cloves, cocoanut shells, and other worthless matter. The presence of spent cloves can be determined only by estimation of the amount of volatile oil present. Clove stems show microscopically a very large

proportion of the so-called stone cells. Other substances are detected in the manner described under Pepper.

CINNAMON AND CASSIA.

Cinnamon is the inner bark of *Cinnamomum zeylanicum*. Cassia is the bark of several species of *Cinnamomum*. In the unground state, cinnamon is thin and delicate; cassia is thick and comparatively coarse. Cinnamon is the richer in volatile oil, and for this reason and because it is found much less abundantly, is considerably more expensive than cassia. Ground cinnamon is practically never found in the market, the substance sold under that name being almost invariably cassia. The common adulterants of cassia include ground shipbread, nut shells, and cedar sawdust.

ALLSPICE OR PIMENTO.

Allspice is the dried unripe berries of *Pimenta officinalis*. Although one of the cheapest of spices, it is adulterated extensively with ground shipbread, charcoal, nut shells, clove stems, and mustard hulls.

GINGER.

Ginger is the rhizome of *Zingiber officinale*. It is one of the most commonly adulterated of condiments. The substances used include ground shipbread, rice, mustard hulls, cayenne, turmeric, cornmeal, clove stems, and exhausted ginger from the manufacture of the tincture. It is very rich in starch, which is differentiated easily from other starches.

NUTMEG.

Nutmeg is the inner kernel of the fruit of *Myristica fragrans*. It is not commonly sold in the powdered condition, but when so sold is generally adulterated with the substances used as admixtures of other spices.

MACE.

Mace is the dried membranous covering, the arillode, of the nutmeg. It is adulterated with wild mace, cornmeal, and other cheap materials.

CAYENNE PEPPER.

Cayenne is not a true pepper, but the powdered pods of several species of *Capsicum*, including *C. annuum* and *C. fastigiatum*. Its appearance under the microscope is very characteristic. The commonest adulterant is cornmeal. Among others are rice, mustard hulls, turmeric, and ground shipbread.

BAKING POWDERS.

Baking powders, like condiments, are in no sense foods, but being employed in the preparation of bread, in which are retained the ulti-

mate products of the reactions of their component parts upon each other, they are of hygienic interest. They are employed for the production, within a short time, of a result which, when caused by the action of yeast, is only slowly brought about; namely, the leavening of bread. Yeast produces the leavening gas, carbon dioxide, through slow fermentation of a part of the carbohydrates; while with the use of baking powders, this gas is disengaged as a result of chemical action of one of the constituents upon another in the presence of moisture, and chemical substances foreign to yeast-leavened bread are left as a residuum in the bread. Whether this residuum is objectionable on the score of its influence upon the system, depends upon the nature of the ingredients of the powder; but aside from the question of disadvantage or inferiority on this account, it is a fact, generally acknowledged, that bread made with baking powder is lacking in a certain agreeable flavor developed by the action of yeast.

Baking powders are combinations of an acid or acid salt with sodium bicarbonate in about the proper proportions for chemical union, together with an amount of starch sufficient to keep the ingredients in a dry state, and hence mutually inactive. When the combination is introduced directly into the flour, and water is added to make the dough, the reaction occurs and carbon dioxide is set free. They are known, according to the nature of the acid salt, as tartrate, phosphate, and alum powders. Tartrate powders are made usually with "cream of tartar" (potassium bitartrate), but occasionally with tartaric acid, which is not only more expensive, but is objectionable from a practical standpoint on account of its readier solubility, which causes a too rapid evolution of gas. The reaction which occurs between potassium bitartrate and sodium bicarbonate has, as results, carbon dioxide, water, and potassium sodium tartrate, or "Rochelle salt"; as follows:

$$KHC_4H_4O_6+NaHCO_3=KNaC_4H_4O_6+CO_2+H_2O.$$

The commercial advocates of other kinds of powders dwell upon the undesirability of aperient substances in bread, but the residuum of Rochelle salt in the amount of bread which one could eat in a day would be very much under the minimum dose from which any results could be expected.

Cream of tartar, as retailed, is adulterated very commonly with gypsum, chalk, alum, and starch; but as furnished to the manufacturer by the refiners, it contains but a very small percentage of a normal impurity, tartrate of calcium. The usual chemical tests and microscopic examination reveal fraudulent adulteration very quickly. Good specimens contain at least 94 per cent. of bitartrate; and 2 decigrams, dissolved in hot water and titrated with decinormal sodium hydrate, require for complete neutralization not less than 10 nor more than 10.6 cc. The presence of a small amount of tartrate of calcium is of no sanitary importance whatever, statements to the contrary in advertising matter notwithstanding.

The phosphate powders are made with acid phosphate of calcium,

which contains ordinarily more or less sulphate as a natural impurity. The reaction with sodium bicarbonate is expressed as follows:

$$CaH_4(PO_4)_2 + 2NaHCO_3 = CaHPO_4 + Na_2HPO_4 + 2CO_2 + 2H_2O.$$

There is no well-grounded objection to the use of this class of powders.

Alum powders are made usually with soda alum and a very large amount, frequently as high as 50 per cent., of starch "filling." Their leavening power is almost invariably far below that of tartrate and phosphate powders of good quality. The cheapest class of powders, the sale of which is promoted by gifts or "premiums" of cheap crockery and glass, are made with alum and the maximum amount of filling. The reaction between alum and sodium bicarbonate is expressed as follows:

$$Na_2Al_2(SO_4)_4 + 6NaHCO_3 = Al_2O_6H_6 + 4Na_2SO_4 + 6CO_2.$$

Whether the alum exerts any injurious effect upon the bread itself, and whether the resulting hydrate or any excess of alum has any sanitary importance, are questions which have been the subject of extensive controversy. Without reproducing the arguments and claims of both sides, it should be said that the weight of scientific evidence is decidedly against the employment of alum in the making of bread. Some of those who believe alumina to be harmless in the amounts consumed, regard powders containing both alum and potassium bitartrate as highly objectionable, the complete precipitation of alumina being prevented. Powders containing alum and acid phosphate are held also to be objectionable, on account of the formation of aluminum phosphate, which is supposed to inhibit gastric digestion.

In addition to sodium bicarbonate, ammonium carbonate is used more or less as a source of leavening gas. While this agent when administered therapeutically may exert a marked temporary influence, the amount used in baking powders is too small to be hurtful to the system.

The amount of starch filling used in making baking powders is very variable. The best grades contain considerably under 20 per cent., and anything over that amount may rightly be regarded as in the nature of unnecessary and fraudulent dilution.

Section 7. FOOD PRESERVATION.

Foods of a perishable nature are preserved in many different ways, but not all methods are equally applicable to all foods. Thus, freezing and salting, while well suited to meats and fish, can hardly be employed with fruit and vegetables; and preservation in sugar syrup, while well adapted to fruits, is not suited to meats. The methods in general use include the employment of low temperatures, desiccation, salting, smoking, canning, and chemical treatment.

Cold.—For the best results of preservation by cold it is not always essential that the food shall be frozen; but unless the temperature to which it is exposed is near or below the freezing-point, the influence is only temporary. Packing in ice serves very well for short periods to ship meats and fish through long distances, and to keep them in satisfactory condition for reasonable periods in the homes of the consumers. There are several methods of applying cold on a large scale in cold-storage warehouses, ocean steamers, and public markets, the principal one being known as the ammonia process, by means of which any desired temperature down to 0° F. may be obtained with but slight fluctuation, provided the walls, floor, and roof of the space occupied are rendered non-conducting by hair-felt, air spaces, and other means. Meats and fish are preserved indefinitely and without deterioration when frozen, but should not be allowed to thaw and freeze; eggs and fruits may be kept many months in dry air at just above the freezing-point.

The advantages of cold as a preserving agent are that, unlike any other, it involves neither the abstraction of any constituent of the food nor the addition of any foreign matter; it neither imparts a new taste nor alters the natural flavor; it causes neither a loss of nutriment nor diminished digestibility; and on the withdrawal of its influence the material is left in its original condition. It should be said, however, that after restoration to the natural condition, the keeping qualities appear to be somewhat impaired, and in consequence the material should be used within a shorter time than is the case with similar fresh food that has not been frozen.

Drying.—Drying is efficient according to the thoroughness of the process. The method is not so well adapted to meats as to vegetables, since it leads to more or less loss of the natural flavors, which are likely to be replaced by others less agreeable in character. Dried meats are, moreover, considerably less digestible than fresh meats. When thoroughly dried and properly stored, both meats and vegetable products can be kept without limit of time. Drying does not insure safety against parasites.

Salting.—In the process of salting, the soluble organic constituents of meat and fish are removed in large part, and the fibers become hardened. The nutritive value and digestibility, therefore, are diminished correspondingly. Brine salting of fish is one of the oldest processes of preservation known.

Smoking.—Smoking consists in exposing the meat or fish to the action of the smoke of wood fires after, as a rule, a preliminary salting. The exposed material, already deprived of part of its natural moisture, becomes dried still farther, and is partly penetrated by acetic acid, creosote, and other preservative elements of smoke. In the quick smoking process, the meat is brushed over with or dipped into pyroligneous acid at definite intervals, and finally dried in the air.

Canning.—In 1804, M. Appert, of Paris, discovered that meats and other foods in sealed vessels would keep indefinitely, if, after being sealed, they were kept for an hour in boiling water. In 1810, he

introduced the method of sealing the vessel after the heating process has driven out the air and replaced it with steam, so that when cooled a vacuum is formed. At the present time, the chief method followed is to pack the cans full and close them completely, excepting a small hole, then to subject them to the temperature of boiling water, or higher, and to close the hole with solder. They are then reheated and finally allowed to cool.

Much has been said for and against this method of preserving foods. The chief objections have been that the natural acids of the foods may corrode the inner surface of the cans and form metallic salts, and that terne plates, that is to say, sheet iron or steel coated with an alloy of two parts of lead to one of tin, may be used instead of the best quality of tin plates. As to the latter objection, while there is in this country no legal restriction as to the character of the tin employed, it is a fact that terne plates are never used. With regard to the possibility of corrosion of the metallic surface, it must be admitted that not only the very acid foods, but even those which are neutral and even alkaline in reaction, almost invariably will yield traces of tin; but there is, at the same time, absolutely no evidence that the small amount present in the entire contents of a can is capable of causing the slightest injury.

There are, it is true, numerous cases of poisoning reported as due to metallic contamination of canned foods, but not one of those which have fallen under the view of the author will stand the test of exclusion of other possible and more probable causes. Of the small amounts of tin found in canned foods, Professor Attfield says that they are undeserving of serious notice, and he questions that they represent the amount regularly worn off of tin saucepans and kettles. Furthermore, it is the nearly unanimous opinion of writers of works on toxicology that the only compounds of tin that are in any way poisonous are the chlorides, and even these are ignored completely by most of the leading authorities.

On the other hand, there is no limit to the testimony regarding the very great value of canned foods, especially in military operations on a large scale, and in expeditions of various kinds away from market centres and other sources of supply. Lieutenant Greely, Dr. Nansen, and other Arctic explorers are unanimous in their praise. Greely, for example, says: "No illness of any kind occurred prior to our retreat, and those most inclined to canned fruits and vegetables were the healthiest and strongest of the party." Lord Wolseley, in speaking of their usefulness in hot climates, says that "tinned provisions, meat or vegetables put up separately or combined in the form of soups, are practically undamageable by any climatic heat" provided they are of the best quality and have been properly cooked and enclosed in perfectly sound airtight tins. "Given these conditions, nothing can be more admirable; failing them, nothing more deleterious." In military operations in the tropics, where beef cattle cannot be taken along on the hoof and refrigerated beef cannot be transported overland on account of speedy decomposition, canned meats are indispensable.

How long properly canned foods will remain in good condition, can hardly be determined, but the evidence at hand points to indefinite preservation. In 1824, according to Letheby, a number of tins of mutton were cast ashore from the wreck of a ship at Prince's Inlet; eight years later, they were found by Sir John Ross, and those which he opened were in good condition, although exposed during this time to alternate freezing and thawing. Sixteen years afterward, they again were found by men from the ship *Investigator;* and in 1868, forty-four years from the time they were cast ashore, the remaining tins, opened by Letheby, were found to be in a perfectly sound state. Tyndall[1] makes mention of tins in the Royal Institution that had remained in good condition sixty-three years.

Professor A. H. Chester, of Hamilton College, relates that in the summer of 1875 he hid a number of cans of corned beef under a stump in woods in the northern part of Minnesota, and five years later found them to be perfectly sweet, although they had been exposed to the heat and cold of five successive summers and winters. Again, a number of cans of meat and fruit, washed into the Genessee River in 1865, were dug out of the mud sixteen years later, and found to be unaltered.

It is an unfortunate fact that the cupidity of some of our largest packing-houses has led to the canning of what is practically refuse meat, from which the constituents to which the desirable flavors are due have been extracted, and that in consequence the public mind has largely become imbued with a prejudice against canned meats in general. But it is not alone in this country that canned meats are sometimes not what they purport to be. It is related that in France, in 1899, a packer of meats was sentenced to pay a fine and to serve eight months in prison for putting upon the market an immense amount of canned game and poultry, all of which had been made from the flesh of broken-down cab horses.

Chemical Treatment.—Chemical preservatives are substances or combinations added to foods with the object of delaying or preventing their decomposition. They are used on the assumption that, while they accomplish the desired object, they are incapable of exerting any harmful influence upon the system of the consumer—an assumption that has not been demonstrated as based on sound reasoning. It is assumed that bad effects cannot be caused, because they are not manifested at once after the ingestion of small doses by persons in good health; but this is no proof that continued use may not result in serious trouble which may be referred to some other possible cause.

It is said that the preparations employed are in common use as valuable remedies in the treatment of the sick; but it should be taken into consideration that, when used as remedies in morbid conditions, they are given for only a limited time, for the purpose of counteracting abnormal influences, and that the doses are regulated carefully under proper professional supervision. Their action in conditions of health

[1] Floating Matters in the Air, New York, 1882, p. 293.

and disease may be very different; but whether so or not, one can find no excuse for the ingestion of curative remedies by a person in a state of health, whose system needs no such aid, for indefinite periods and with no regulation of the size of the dose. Salicylic acid, for example, is a remedy holding a high position in the treatment of rheumatism, but its value in this condition is no valid excuse for its administration day in and day out to those who never have felt the twinges and pain of this disease. It is much more reasonable to assume that drugs which exert a powerful influence for good in morbid states will exert an equal degree of influence for harm in conditions of health. Moreover, it is to be considered that the object of chemical treatment of foods is not to benefit the unconscious consumer, but to bring the largest possible financial return to the manufacturer and purveyor, to whom the health of the consumer may be a matter of little concern. In all fairness to the consumer, chemically preserved foods should be so labelled that the purchaser may be informed of the nature and amount of the added substance, so that those who object to the dietetic use of drugs may not have the same forced upon them without their knowledge.

The addition of preservatives to foods offered for sale is forbidden in almost all civilized countries, and several governments have enacted laws specially directed against individual drugs. Thus, France names boric acid, borax, salicylic acid, and sodium bisulphite; Austria names salicylic acid; Germany prohibits all antiseptics, and especially boric acid and borates, and imposes additional penalties for the sale of chemically preserved foods to the navy. Massachusetts prohibits all preservatives except salt, sugar, niter, vinegar, and alcohol, unless the purchaser is informed of the nature of the substance used. In milk, all preservatives whatsoever are prohibited unconditionally.

The substances used as chemical preservatives include boric acid and borax, salicylic acid, sulphurous acid, sulphites and sulphates, benzoic acid, formaldehyde, hydrogen peroxide, sodium fluoride, and others of minor importance. Many of the commercial preparations in common use are combinations of two or more of these and other substances. Thus, Venzke and Schorer[1] report the ingredients of 38 meat preservatives, analyzed by them, as follows: Salt, sugar, and saltpeter, (1); salt and sodium sulphite and sulphate (4); sodium sulphite and sulphate (4); the same, plus sugar and salt (1); salt and sodium bicarbonate and nitrate (1); salt, boric acid, saltpeter, and sodium sulphate (3); salt, boric acid, and sodium sulphate (1); salt, boric acid, gypsum, and sodium sulphate (1); salt and boric acid (6); salt, saltpeter, sodium and calcium sulphates, and cochineal (1); salt and borax (1); salt, borax, and saltpeter (2); salt, borax, and sodium nitrate (2); salt, borax, sodium and calcium sulphates, and salicylic acid (1); borax and sugar (2). The rest consisted of single substances.

A large proportion of 24 meat preservatives examined by Kämmerer were found to be mixtures of borax and boric acid, and borax and sodium sulphite; 31 others examined by Kionka were, as a rule, sodium

[1] Deutsche Fleischerzeitung, 1893, XXI., Nos. 20, 21, and 24.

sulphite and sulphate, but 14 liquid preparations consisted chiefly of calcium sulphite and sulphate, and sodium sulphite, bisulphite, and sulphate. Kirchmaier has reported one as consisting of salicylic acid and sodium salicylate and phosphate. Polenske found boric acid (about 60 per cent.), saltpeter (about 12–14 per cent.), sugar, salt, and sodium salicylate (about 7.50 per cent.) in a specimen of sausage salt, and in a number of other preparations sold under fancy names. Of 7 other meat preservatives examined by him,[1] one contained salt, sodium sulphite and sulphate, iron chloride, and vanillin, and the rest were combinations already described.

A. C. Chapman[2] has reported a most extraordinary combination of aluminum sulphate, salt, sodium nitrate, benzoic acid, iodic acid, sulphurous acid, and chloral.

Another, examined by Töllner, proved to be ammonium bromide, boric acid, borax, and sugar. Another, known as "Mayol," contained wood alcohol, ethylic alcohol, boric acid, ammonium fluoride, and glycerin. Meats preserved by means of it are said to show no trace of boric acid or ammonium fluoride beneath the brown coating, which forms to a depth of a millimeter.

In this country, the favorite mixture is one of borax and boric acid, and this is sold under many different names.

Boric Acid and Borax.—These substances generally are used together, for the reason that, although the acid has greater power as an antiseptic than the salt, the combination of the two is still more efficient. It is used very largely in butter to the extent of about a tenth of an ounce to the pound, and is dispensed with a generous hand in oysters, clams, and other fish, in sausages and other meat products, and in milk.

With regard to the effects of boric acid and borax on the system, there is a decided difference of opinion among those who have investigated the subject, but it should be said that a number of the reports favorable to the use of these agents, published by commercial houses, suggest that the conclusions arrived at were inspired somewhat by financial considerations. Our knowledge of possible ill effects is derived chiefly from the clinical experience of those who have used the drugs internally and as washes and injections. It is a fact that many patients can take large doses of both substances for long periods with no apparent harm, but it is equally true that small doses and local applications have been a frequent cause of serious and even fatal results. Deaths have been reported from the use of 5 per cent. solutions in washing out the pleural cavity and lumbar abscesses, and from washing out a stomach with a solution of half that strength. Numerous cases of troublesome cutaneous eruptions and of serious gastro-intestinal disturbances following internal and external use have been reported within recent years. Plaut[3] has shown that internal use may be followed by acute parenchymatous nephritis, and his conclusions have been endorsed by the experience of Féré, mentioned below.

[1] Arbeiten aus dem kaiserlichen Gesundheitsamte, VIII., p. 686.
[2] Analyst, Dec., 1898.
[3] Inaugural dissertation, Würzburg, 1889.

In 1876, the admixture of borax to butter was sanctioned officially in France; but seven years later, a committee of scientists, who investigated the matter with great care, concluded that continued ingestion is likely to cause deterioration of the blood corpuscles; and when, somewhat later, this finding was confirmed by the investigations of Pouchet, the use of borax was prohibited by the government, not only in butter, but in all articles of food. In 1891, the subject was presented by the Kensington Vestry to Sir Andrew Clark, Sir Henry Thompson, and Professor Lauder Brunton, who concurred in pronouncing boric acid in large doses, or in small doses taken for long periods, as dangerous to health. The Local Government Board, in 1891, reported that, while large doses are undoubtedly injurious, they had not sufficient evidence to hold that minute amounts added to foods can affect the system harmfully.

As is well known, borax has been used extensively in the treatment of epilepsy and other diseases of the nervous system. Professor H. C. Wood states that, in his experience, the most marked result from its use in this direction was severe gastro-intestinal irritation. Dr. Féré[1] has given a valuable report of his results in the treatment of 122 cases of epilepsy by this drug, which was given in beginning doses of 30 grains, increased to as much as 5 drachms a day. In more than 70 per cent. of the cases, the treatment had no beneficial result; in about 20 per cent., some temporary or doubtful improvement was seen; and, in 9 per cent., there was distinct gain. But the great drawback was the frequency of toxic effects and the danger of producing or aggravating lesions of the kidneys, even when given in small doses. Among the most common results were loss of appetite and burning pain, followed by nausea and vomiting. Cutaneous affections were very common, and complete baldness was caused not infrequently. (This result has been noted by many other practitioners.) In some cases, a cachectic condition, characterized by wasting, a waxy tint of the skin, puffiness of the face, and even general œdema, was observed. In a number of cases of general œdema, uræmia developed with some suddenness.

Dr. Grumpelt[2] has reported a case in which headache, nausea, and intense dryness of the skin followed the use of an injection containing a tablespoonful of boric acid to the pint. The effects disappeared with cessation of the treatment, but came on again with its renewal. Dr. J. J. Evans[3] has found, as a common result of the continued use of boric acid in cystitis and urethritis, an erythema followed by desquamation. Internal doses of 10 to 20 grains twice daily for five weeks caused in one instance total baldness.

Experiments on man and animals, by Professors Mattern, Förster, Chittenden, and Schlenker, have demonstrated that boric acid and borax interfere with digestion and nutrition. Mattern reported profound disturbances in dogs after a few daily doses of 8 grains;

[1] Revue de Médecine, September, 1895.
[2] British Medical Journal, Jan. 7, 1899. [3] Ibidem, Jan. 28, 1899.

diarrhœa and other signs of gastro-intestinal irritation, and in some instances even fatal results were caused. He himself took 30 grains, and suffered violent abdominal pain and diarrhœa. Förster and Schlenker have shown that doses of 8 grains have a decided effect in preventing absorption of nutriment and causing intestinal irritation.

Dr. Annett, of Liverpool, fed a number of kittens with milk containing 20 grains of boric acid to the quart, and all of them died in an emaciated condition at the end of the third or fourth week.

As to the effect of these agents on the different processes of digestion, there is no agreement. Chittenden, for example, believes that boric acid increases the digestion of proteids, and that even 25 per cent. will not check gastric digestion of egg albumin. He has noted also a marked stimulant effect on pancreatic digestion of proteids following the use of borax. Leffmann and Beam, and others, however, have observed effects directly contrary to those reported by Chittenden. Chittenden's first experiments were made to determine the possible influence of borax and boric acid upon the processes of salivary, gastric, and pancreatic digestion. He calls attention to the fact that his results throw no light upon the influence of the agents upon the secretion of the digestive fluids. He shows that borax inhibits the action of saliva on starch, and boric acid in small amounts increases it, and also the power of the gastric juice to digest proteids. Later experiments by Chittenden and Gies[1] lead them to the conclusion that the two substances have no peculiar action on nutrition, and that, since elimination is complete within thirty-six hours, the possibility of cumulative action must be very small, even when moderate amounts are ingested daily.

Tunnicliffe and Rosenheim[2] concluded, from a series of metabolism experiments on young children, that boric acid in doses up to 1 gram per day, continued for some time, exerts no influence on proteid or phosphorus metabolism, has no effect on the assimilation of fat, and exerts no inhibitory effect on intestinal putrefaction; that borax in continued doses of 1.5 grams may or may not improve assimilation of fat, and tends to increase intestinal putrefaction; that both boric acid and borax are eliminated quickly; and that neither will affect the general health and well-being.

Halliburton,[3] experimenting with borax and milk *in vitro*, found that 1 part of borax in 1000 completely prevents the action of rennet, and that smaller amounts delay it.

On the other hand, Liebreich,[4] experimenting with dogs, found that neither borax nor boric acid has any influence on metabolism; that boric acid in saturated solution has no effect on the mucous membranes of the stomach and intestine, while borax in 2 per cent. solution has a

[1] New York Medical Journal, February 26, 1898.
[2] Journal of Hygiene, April, 1901, p. 168.
[3] British Medical Journal, July 7, 1900, p. 1.
[4] Vierteljahrsschrift für gerichtliche Medicin, 1900, p. 83.

markedly injurious effect, though not so much as 1 per cent. of sodium hydrate or 0.5 per cent. of saltpeter; that 5 per cent. of boric acid and 0.25 per cent. of borax have no influence on gastric digestion, but 0.5 per cent. of borax has slight inhibitory action; that neither has any effect on the digestion of starches; and that both are eliminated quickly, and have no tendency to accumulate in the system.

During a period of 19 weeks the author[1] fed borated meat to 6 of 12 healthy cats, which were kept in separate cages under precisely similar conditions. Of the other 6, 1 was kept as a control, and 5 were fed on meat containing another kind of preservative. The average daily dose of borax ranged from 544 to 857 milligrams. During the experiment only 3 of the 12 cats showed any acute sickness, but they were all members of the borax group. One of them died at the end of the sixth week, but the others recovered and were apparently well when the experiment was brought to a close. The cats were killed and all (including the one that died) were subjected to careful microscopical examination. The control-cat showed no lesions whatever, and those fed on non-borated food showed only slight and inconstant changes in various organs; but the borax-fed animals showed without exception lesions of the kidneys of the same general character, yet differing in intensity, and analogous to those found in subacute and chronic nephritis in man. In some cases the degeneration was of an intense character.

Considering all the evidence, conflicting though it be, and the many reports of untoward results of large and small medicinal doses and from absorption of both agents from local applications, it seems not unreasonable to conclude that the daily ingestion of variable amounts in food and drink by persons of all ages cannot be wholly free from objection. A very common practice is the addition of a mixture of the two or of either alone to milk, in the proportion of 1 part in 500 or 1000; a pint will, therefore, contain a fair-sized adult dose, an amount which, taken twice daily, or oftener, by a bottle-fed child, can hardly fail to have some effect not wholly for its well-being.

Salicylic Acid.—Salicylic acid is more efficient than borax and boric acid as a preservative, but cannot be used so generally, because of its tendency to cause unpleasant flavors in foods having a bland taste. It is used extensively in jams, jellies, tomato catsups, bottled beers (especially those from Germany), the heavy beers innocently consumed by total abstainers under the name of "malt extracts," fruit juices, soda-water syrups, cider, wines, and other saccharine preparations, and preserved vegetables. Concerning its objectionable nature as an addition to foods, there is practical unanimity. It not only exerts an inhibitory action on digestion, but acts also as an irritant, especially to the kidneys, by which organs it is excreted. Its addition in any quantity to articles of food or drink is forbidden expressly in many European and South American countries. Its addition to beer and other articles intended for export is permitted in Germany.

[1] American Journal of the Medical Sciences, September, 1904.

Sulphites.—Sodium sulphite and bisulphite and sulphurous acid are used more or less extensively for preserving meat, beer, wine, and for bleaching vegetables (especially asparagus and corn), put up in cans and glass jars. Sendtner has found from 26.4 to 482.6 milligrams of sulphurous acid in 32 specimens of such vegetables, and Kämmerer and others have reported amounts ranging from 3 to 250 milligrams per liter in red and white wines. The author[1] found from 0.061 to 1.225 (average 0.335) per cent. by weight of sodium sulphite in 50 specimens of "Hamburg steak" bought in the markets of Boston.

Kionke[2] has shown that large doses of sulphites exert a marked and sometimes fatally poisonous action on warm-blooded animals, and that small doses, long continued, may affect dogs very seriously. The author[1] fed a number of cats for 20 weeks with meat containing 0.20 per cent. of sodium sulphite, which is the amount recommended as a preservative, and at the expiration of that time the cats were killed and examined. In each case the kidneys showed extensive degenerative changes.

Sodium sulphite is used very commonly in sausages and chopped meat (Hamburg steak), both as a preservative and to cause the bright-red color of the fresh meat to be retained unaltered. Chopped meat keeps its color but a very short time, and as the purchaser will not accept it when not bright red, the vendor is driven to make its appearance acceptable. Thus, the purchaser, insisting upon having what to his eye is freshly chopped wholesome meat, may be served with stale meat containing a most undesirable chemical preservative. In 1898, the Imperial Board of Health of Germany forbade the use of sodium sulphite in foods, because of its dangerous properties.

Formaldehyde.—On account of its property of hardening tissues, formaldehyde does not lend itself to general use as a food preservative. Fish and meats are rendered so hard by very dilute solutions, even 1 to 5,000, as to be worthless commercially. It is used most commonly in milk and other liquids, and acts most efficiently in delaying and preventing decomposition. Its use in milk is, however, far from commendable, for although efficient as a preservative, it alters the character of the proteids, which are thereby made less digestible. The casein, when precipitated, does not separate in fine clots, but in tough, heavy curds, which yield only with much resistance to pepsin and hydrochloric acid. Weigle and Merkel[3] have shown that the proteids are made much less digestible, and their conclusions are in agreement with those of most investigators of the subject. Bliss and Novy,[4] after a most careful and exhaustive inquiry into the effects of formaldehyde on the digestive ferments, found that pepsin and trypsin have diminished action upon fibrin which has been altered by it in very weak solution; that casein is altered rapidly, and, as a result, is not

[1] Boston Medical and Surgical Journal, May 25, 1904.
[2] Zeitschrift für Hygiene und Infectionskrankheiten, XXII., p. 351.
[3] Forschungsberichte über Lebensmittel, etc., 1895., II., p. 91.
[4] Journal of Experimental Medicine, 1899, p. 47.

coagulated by rennet or, at best, very slowly, and is not readily digested by the proteolytic ferments; and that pepsin and rennet are themselves not affected by fairly strong (4 and 5 per cent.) solutions acting for several weeks. Pepsin was found to be affected quickly by very dilute solutions, trypsin to be affected according to the amount of organic matter present, and amylopsin and ptyalin to be not destroyed by very dilute solutions. The latter, however, were found to be destroyed by strong solutions.

Halliburton[1] found that 0.5 per cent. of formalin renders gastric digestion of fibrin almost impossible; and that 0.05 per cent. considerably delays it. Its effects on pancreatic digestion were even more marked.

Tunnicliffe and Rosenheim,[2] experimenting with young children, found that, in doses of 1 part in 5,000 of milk or 1 in 9,000 of total food and drink, formaldehyde exerts no appreciable effect on nitrogen and phosphorus metabolism or on fat assimilation, but in larger doses, or long continued, it may tend to diminish phosphorus and fat assimilation, on account of its effect on pancreatic digestion. With delicate children, the 1 : 5000 dose has a measurable deleterious effect on the nitrogen, phosphorus, and fat assimilation, and exerts a slight irritant action on the intestine. They conclude, however, that, as used, the substance has no influence on the general health and well-being of children. On the other hand, feeding experiments, conducted by Dr. Annett with kittens, demonstrated that, as the amount mixed with the milk was increased, the retarding action on their development was more marked.

Whatever may be the results of experiments tending to show the effects of formaldehyde on metabolism and growth, everybody who has occasion to handle even very dilute solutions can testify to its irritant effects on the skin; and, this being the case, it seems hardly reasonable to assert that the much more delicate mucous membranes of the digestive tract can be subjected to its action and wholly escape injury. Formaldehyde is not generally regarded as a poison in small doses, but a number of deaths have been attributed to its use as a milk preservative, though it should be said that the evidence in these cases will hardly bear critical analysis. One undoubted case of non-fatal poisoning has been recorded by J. Klüber.[3] The subject was a man of forty-seven, who swallowed some aperient water into which formalin had been introduced accidentally He lay for a long time in a state of coma, and had anuria nineteen hours. Formic acid was eliminated in the urine during recovery.

Hydrogen Peroxide.—This agent is recommended as the least dangerous of all chemical preservatives, and is believed by some to exert no deleterious effect whatever. It is well adapted for use in wine, beer, and fruit juices. One part in 1,000 is said to prevent entirely the

[1] Loco citato.
[2] Journal of Hygiene, July, 1901, p. 321.
[3] Münchener medicinische Wochenschrift, October 9, 1900.

alcoholic fermentation of glucose solutions, and in somewhat larger amounts to prevent the formation of lactic acid in milk.

Sodium Fluoride.—So far as is known, sodium fluoride exerts no poisonous action, but its effect on digestion has not been studied thoroughly. Perret[1] asserts that it has a decided influence in inhibiting the development of lactic and butyric ferments. Using himself and a number of dogs, he undertook a series of feeding experiments, and concluded therefrom that the salt is in no way poisonous, and may be used without danger as a food preservative. Specimens of milk containing 3 parts in 1,000 and kept at 38° C., remained unchanged long after the controls had become coagulated. A dozen tubes of milk containing it, and planted with butyric ferment, and another dozen containing untreated milk similarly planted, were kept side by side at 38° C.; on the day following, the latter were coagulated, but the former were unchanged. Subcutaneous injections of the salt to the extent of 0.08 gram per kilogram of weight caused in a dog slight salivation and diuresis; but larger doses caused marked salivation, diuresis, thirst, and refusal of food. Intravenous injections of 0.10 per kilogram caused immediate rise of pulse and respiration, followed by abundant salivation, nausea, convulsions, and death in thirty-five minutes. Leffmann and Beam[2] have noted that sodium fluoride interferes but little with the digestion of starch.

Sodium fluoride appears to be weak as a general preservative, but prevents alcoholic fermentation completely when present to the extent of 1 part in 2,000. The fluorides and hydrochloric acid are used by some brewers for the prevention of undesired fermentations.

Sodium Bicarbonate.—This agent seems to be as little objectionable as any, but it is very weak in its preservative action and is too ineffective for general use. It is used somewhat in Sweden in conjunction with sugar for meat and fish. A more common use is to overcome beginning acidity of milk; against this is urged the possibility of purgative effects in infants, through the sodium lactate produced.

Section 8. CONTAMINATION OF FOODS BY METALS.

Not infrequently, small amounts of metallic salts are present in foods, either through accident or by reason of intentional admixture for some definite end. The most common are compounds of copper and of lead, and these are regarded as of greater hygienic importance than the salts of zinc, tin, and nickel occasionally present.

Copper.—Copper gains entrance through the improper use of cooking utensils of brass and copper, and through the use of its salts for greening peas and other vegetables ("reverdissage"), and for improving flour of inferior grade. Copper and brass kettles yield small amounts to acid, fatty, and other foods allowed to stand therein, espe-

[1] Annales d'Hygiene et de Médecine légale, June, 1898, p. 497.
[2] Journal of the Franklin Institute, 1899.

cially if the contents are exposed to the air. Their yield is much greater if they are not kept thoroughly clean and well polished. Lehmann[1] found 36.8 milligrams of copper in a liter of broth made in a brass vessel and allowed to stand 24 hours, 8.7 mgr. in 100 cc. of rancid fat allowed to stand 2 weeks, 21 mgr. in a liter of sour wine, and 61 in the same volume of vinegar after 24 hours. Mair has reported 24 mgr. in a liter of rice soup after 24 hours.

The use of copper for greening vegetables is exceedingly common. It serves no useful purpose other than to please the eye. The peas or other vegetables are boiled in a very dilute solution of copper sulphate, drained, washed, and, finally, put up in cans or glass jars. The artificial color, which is often much more intensely green than the natural, is due to an organic compound of copper which is insoluble in water. The claim sometimes urged, that the copper serves to fix the chlorophyll, and is not itself retained, is preposterous, for if a solution of chlorophyll is heated with dilute copper sulphate, the color is destroyed and a brown precipitate is produced; while if perfectly white beans are boiled for a short time in a solution of the same strength, they take on a deep-green color through the formation of a new compound with the contained legumin or some other proteid. Potatoes, being very poor in proteids, are affected but slightly by similar treatment, but eggs may be colored intensely green.

The liquor of canned greened vegetables is commonly free from copper, and the testing of specimens by adding ammonia to a portion of the liquor, in the expectation of producing a blue color in case the vegetable has been so treated, is, therefore, without result. In order to determine the presence of copper, a few grams of the substance may be incinerated in a porcelain capsule, the residue therefrom treated with dilute hydrochloric acid, and the filtrate subjected to the usual tests.

The question of the hygienic importance of small amounts of copper has been the subject of a number of extensive investigations on the part of individuals and foreign governments, and while it can hardly be said to be proved that danger can arise therefrom, nevertheless no good reason can be advanced in favor of the practice of greening. Two students in Lehmann's laboratory took daily doses of copper salts with no perceptible disturbance; one took 39 milligrams of copper sulphate daily for 50 days, and then double that amount for 30 more; the other took the acetate for 51 days in doses ranging from 16 to 96 milligrams. These amounts are larger than an average eater would be likely to take into his system from canned vegetables in the course of a day, for the entire contents of an ordinary tin—somewhat less than half a pound—commonly yield less than 50 milligrams of copper.

According to Baum and Seelinger,[2] whose numerous experiments extended over a period of three years, small daily doses are, as a rule, completely absorbed and again eliminated; larger doses are not completely absorbed. Complete elimination may require as long as five

[1] Seventh International Congress of Hygiene, 1891.
[2] Zeitschrift für öffentliche Chemie, 1898, p. 181.

months from the date of the last dose. Long-continued ingestion of small doses may bring about a condition of chronic poisoning.

Copper appears to be a normal constituent of some articles of food. The assertion, made originally by Meyer, of Copenhagen, that wheat and oats often contain minute traces, especially in their husks, has repeatedly been proved. According to Lehmann,[1] the species of plants has far less influence on the amount taken up than the amount of copper present in the soil. He found the metal in a great variety of plants growing in a copper soil: rye, oats, hops, potatoes, dandelion, juniper, violets, cherries, etc. In woody plants, the greatest amount of copper is in the bark. According to Karsten,[2] the spraying of grapevines with copper solutions is not wholly free from objection, since that which adheres to the fruit may be sufficient to make their yield of wine toxic. He instances a number of cases of diarrhœa and vomiting due to wine which yielded traces of copper.

Lead.—Traces of lead are of common occurrence in various articles of food, especially those wrapped in foil or enclosed in cans having exposed seams of lead solder. A number of specimens of wrapping-foil, analyzed by Dr. Charles P. Worcester,[3] yielded lead in amounts ranging from traces to 89 per cent. They are used largely for wrapping cream cheeses, chocolate, and other foods. The metallic caps used for closing glass jars of preserved fruits and vegetables are also sources of danger. One specimen examined by Worcester contained 93.5 per cent. of lead. Patent stoppers, consisting of a metallic disk with a border of rubber, used in bottles for summer beverages known to the trade as "soft drinks," commonly contain lead, as is shown by Worcester's examination of 28 specimens, which yielded from 3.5 to 50.7 per cent. The contents of the several bottles yielded lead without exception; the largest amount was 1.05 milligrams.

Dr. William R. Smith[4] has drawn attention to the common occurrence of lead in citric and tartaric acids. The former is used considerably in making summer drinks, and the latter in effervescing powders and baking powders. Of a dozen specimens examined by him, only one was uncontaminated; the highest amount found was 0.037 per cent.

At the present time, canned foods are less likely to show traces of lead than formerly, when the cans were made with less care. In 1893, Wiley[5] reported traces in 132 out of 248 samples examined.

Concerning the hygienic importance of small daily doses of lead, there is but one opinion. It is quite improbable that the occasional use of canned vegetables containing but a fraction of a milligram in an entire can will lead to serious injury, but the constant daily ingestion of appreciable amounts of lead is likely to lead to serious consequences in at least a fair proportion of cases.

[1] Archiv für Hygiene, XXVII., p. 1.
[2] Chemiker-Zeitung, 1896, p. 37.
[3] 29th Annual Report of the State Board of Health of Massachusetts, p. 570.
[4] Journal of State Medicine, October, 1892.
[5] Department of Agriculture, Division of Chemistry, Bulletin No. 13, Part VIII.

Especially to be avoided are the acid drinks contained in bottles with lead stoppers. The amount of lead present is small, and an occasional indulgence is unlikely to cause harm; but cases of serious injury have occurred. In one, in which the cause of the trouble was investigated by the author, the patient, a temperance lecturer, had for some weeks been passionately addicted to the use of a particular brand of effervescent drink known as "strawberry tonic," a carbonated, acidulated solution of sugar, flavored with an artificial compound ether, and colored with an anilin dye. Evidence of chronic lead poisoning developed with some suddenness, and in a short time not only wrist-drop, but also toe-drop appeared. Specimens of the beverage were examined. The stoppers were almost pure lead, and the contents of each bottle yielded notable traces of the metal.

Zinc.—Zinc sometimes occurs in small traces in canned foods from the use of the chloride in soldering. With improved methods, in which another flux is employed, this contamination is becoming uncommon in this class of foods. It appears to be a common accidental impurity in dried apples, from contact with galvanized iron wire racks on which they are cured. Kämmerer[1] found it in 4 out of 9 specimens of American dried apples; the average amount, reckoned as malate, was 0.0656 per cent. Bujard[2] found it in 37 out of 54; in 20, the amount present ranged from 0.03 to 0.49 gram to the kilogram, reckoned as oxide; in 17, it was present only in traces. We have no evidence that these small amounts are of the slightest sanitary importance.

Nickel.—Nickel is employed sometimes in place of copper for greening peas. About a quarter of a gram of the sulphate suffices for a kilogram of peas. It is dissolved in boiled water to which 10 cc. of a 2 per cent. solution of ammonia are added, and then the solution is diluted with boiled water in sufficient amount to cover the peas, which then are boiled for a few minutes, drained, and washed. According to E. Ludwig,[3] nickel is given off in small amounts to all sorts of foods cooked in nickel dishes. He found from traces to 12.9 milligrams per 100 grams of the food examined. There is no evidence that these amounts can produce injury.

Tin.—Contamination with compounds of tin is exceedingly common, and, so far as is known, is harmless and unimportant, the compounds, other than the chloride, being apparently incapable of producing any physiological or local action.

Metallic Contamination from Kitchen Utensils.—Much has been said, from time to time, concerning the possible danger of poisoning by small amounts of lead and other metals taken up by foods from kitchen utensils, and especially from glazed earthenware; but a number of extensive investigations have demonstrated that this danger is very remote. Mussi[4] has shown that, if the firing of lead-glazed pottery

[1] Chemiker-Zeitung, 1897, p. 721.
[2] Forschungsbericht über Lebensmittel, etc., 1897, IV., p. 218.
[3] Oesterreiche Chemische Zeitung, 1898, I.
[4] Giornale della R. Società Italiana d'igiene, January 30, 1900, p. 1.

has been done properly, no trace of lead will be taken up by acid foods, such as tomato soup, or even vinegar; but he advises that all new vessels should be cleansed very carefully before using, on account of the common presence of lead dust on the glaze when fresh from the kiln. Riche[1] also determined that with properly fired ware the danger of solution of lead is practically *nil*, the specimens used yielding no traces to boiling dilute acetic and nitric acids and salt solutions. But improperly fired ware will yield traces.

Enamelled ware is believed commonly to contain lead; and the enamel, having a different coefficient of expansion from that of the iron, being likely to crack and chip off, especially with careless handling, is thought to be dangerous; but Barthe[2] found no trace of lead in a number of enamels examined, and asserts that very hard enamels need neither lead nor any other poisonous compounds in their preparation. This accords with the experience of the author and other American investigators, and it may confidently be said that the enamelled ware in common use is lead-free.

Aluminumware, which has of late come into extensive use, is less acted upon by acid foods than tin, but is affected considerably by alkalies, the impurities present in commercial aluminum acting as favoring agents to its corrosion. But the resulting compounds are innocuous in the small amount ingested. This kind of ware is kept clean very easily and offers the great advantage of lightness.

Nickelware is attacked but slightly by ordinary food materials, and the amounts taken up are without sanitary significance. But its cost is against its extensive use, and, moreover, it imparts sometimes a greenish tint, which is repugnant to the eye.

[1] Revue d'Hygiène, August 20, 1900, p. 704.
[2] Journal de Pharmacie et de Chemie, 1898, p. 105.

CHAPTER II.

AIR.

Air is a mixture of gases, and not a chemical compound. Until the latter part of the seventeenth century (1669), it was supposed to be an element, but Jean Mayow then proved it to be a mixture of gases; and later, Lavoisier discovered the two gases, oxygen and nitrogen, which, a hundred years later, were separated by Priestley and by Scheele.

Air is a colorless and apparently odorless mixture of oxygen, nitrogen, argon, carbonic acid, aqueous vapor, and traces of other substances. It is not, however, under ordinary conditions odorless, but, on the contrary, it contains various scents, to which we are so accustomed that, unless present in unusual degree, owing to local conditions, they are not perceived. This is noticed on returning to an ordinary atmosphere from one where the causes of the usual odors are absent or nearly so, as, for instance, from deep subterranean caves; or from a room where the air is foul and oppressive, as, for instance, from a heated, overcrowded hall or street car. The air of the Arctic regions contains but little odor, on account of the absence of bodies which give rise to odors, and the proximity of any source of smell is noticed quickly. The explorer Nansen[1] speaks of the pervading smell of soap which he noticed when, after months of wandering, he met Jackson, who had been housed comfortably with all the common necessities of man.

While air is a mixture of gases, it is one of tolerably constant composition, particularly in the case of its chief constituent, nitrogen. Under the conditions of life, the more important, but less abundant element, oxygen is subject to more or less variation. In the presence of vegetable life, particularly by day, it is increased slightly; in the presence of animal life, it is diminished more or less.

OXYGEN.

The normal amount of oxygen is stated usually at just below 21 per cent. by volume. A. Leduc gives it at exactly 21, with 78.06 of nitrogen and 0.94 of argon. Different observers have reported the following as averages of large numbers of analyses of pure outdoor air:

20.99	Scotland.
20.98	Scotland.
20.94	Sweden.
20.92	France.
20.94	Germany.
20.92	Norway.
20.95	England.
20.95	Ohio.

[1] Farthest North, Vol. II., p 529.

The mean of a number of analyses by Bunsen was 20.924 by volume, and of a hundred at Paris by Regnault, 20.960. For the sake of convenience, we may disregard the very slight difference between 21 and the figures obtained by exact analysis, a difference in the second place of decimals, and accept 21 as a normal. At great heights, the proportion of oxygen is less than at the surface. For instance, on the Faulhorn, in Switzerland, 20.77 has been observed as the mean of a number of determinations. Under certain conditions, there is very slightly more than 21 parts; for instance, in the immediate vicinity of vegetation, especially by day, there may be an excess of oxygen, but it is very small; sea air, taken in mid-ocean, has yielded 21.59, but ordinarily contains less than 21. It is less, by very small fractions, in the streets of cities than in the open country, and in towns than at sea.

Oxygen is the element in air that supports all life. It is constantly being withdrawn from the air in the process of respiration, and is returned to it in chemical union with carbon as carbon dioxide. This is absorbed by vegetation and split up, the carbon being retained, and the oxygen for the most part released and returned to the air. Thus, the processes of animal and vegetable life combine to maintain the equilibrium.

All animals do not breathe in the same degree; birds have the most active respiration, and next come mammals; and all consume more oxygen when active than when asleep.

Oxygen is essential to the germination of seeds, and to the growth of plants. Although plants take up carbon dioxide and exhale oxygen, they also breathe as do animals, absorbing the latter and exhaling the former. Even the anaërobic organisms consume oxygen, although living where air is wanting, for they split up combinations of oxygen and other elements. Thus, in dilute sugar solutions they withdraw some of the oxygen and split up the sugar into carbon dioxide and alcohol.

For sustaining animal life, it is essential that the air shall contain not far from the normal amount of oxygen; that is, that it shall be neither much diminished nor yet over-rich in that element. Human life is impossible in air which contains but four-fifths of the normal amount, and equally so in an artificial atmosphere containing materially more than the normal.

In man and animals, the tissues do not receive oxygen in the free condition, for when the air is inspired, the oxygen is taken up by the red blood corpuscles and unites with the hæmoglobin to form an unstable compound, oxyhæmoglobin, which, as the blood circulates through the tissues, is decomposed; the oxygen is then taken up by the cells, and eventually returned to the blood in the form of carbon dioxide, and eliminated as such from the body. In an artificial atmosphere containing an excessive amount of oxygen, the hæmoglobin becomes saturated with the gas, part of which becomes dissolved in the blood serum, and then acts as a poison to the tissues and destroys them.

Inspired air loses about a fourth of its oxygen, and is returned to the atmosphere rich in impurity; but diffusion occurs so rapidly that the atmosphere of a thickly settled city shows no very material variation from that of the open country.

The lungs are never filled with pure air after the first respiration at birth, since they are never wholly emptied, and they consequently contain an impure residue of air after each expiration. The upper part of the respiratory tract is the only part that receives strictly pure air. Professor Richet has demonstrated that, if the respiratory tract be lengthened artificially by means of a rubber tube, pure air will never reach even the upper air-passages, and the animal will die of asphyxia.

The amount of oxygen absorbed varies with age, condition of health, and activity. According to Professor Foster, an average person inhales in 24 hours about 34 pounds of air, which corresponds to a little more than 7 pounds of oxygen; and as the lungs absorb about a fourth of the oxygen inhaled, it appears that the average amount of oxygen absorbed daily is nearly 2 pounds.

NITROGEN.

The principal constituent of the air, nitrogen, takes no part in respiration, and is not increased in expired air; but although it is indifferent and inert, it is, nevertheless, by no means unimportant. In the first place, it serves to dilute the oxygen, so that the latter is respirable; and in the second place, it plays an important part in the growth of plants, the original source of all nitrogenous food, for that which we consume in the form of meat is from animals that have built up their tissues from vegetable food. As a diluent of oxygen, it serves to prevent too great activity of that element, which cannot be breathed with impunity for any length of time when present in an atmosphere to a greater extent than its normal amount.

How nitrogen is absorbed by plants, we know only in part. Certain low forms (mycelia, etc.) seem to absorb it directly from the atmosphere when exposed freely to light and air. Some of the higher forms (peas, beans, clover, etc.) acquire it through the agency of certain micro-organisms which are present in nodules in their roots, and without which they will not thrive. These micro-organisms take the nitrogen from the atmosphere and give it in some form to the plants. That this is so, is proved by the fact that the plants will thrive in a soil quite free from nitrogen (in clean sand, for instance), and store up in their tissues an amount of nitrogen far in excess of that which was originally present in the seeds, provided these micro-organisms are present in the nodules of the roots. If they are not present, the plants will not thrive, but may be made to do so by the application of water containing cultures of the organisms. Of the doubtless many species which can fix atmospheric nitrogen, or which aid in doing so, the following may be mentioned: *B. megatherium*, *B. fluorescens liquefaciens*, *B. proteus vulgaris*, *B. butyricus*, *B. mycoides*, *B. mesentericus vulgatus*.

On the other hand, certain plants, grown in the open air in soils free from nitrogen, and protected from receiving ammonia and nitrates from the rain, will show no more nitrogen in their whole organization than was present in the seeds from which they sprang. The subject is one which has been investigated but partly, and future research will doubtless show that, under natural conditions, all plant life takes up in some way more or less nitrogen from the atmosphere, as well as from nitrogenous compounds in the soil.

ARGON.

Up to the time of its discovery, the element argon was included under nitrogen in the tables of composition of the air. How much is present, is not yet accurately determined. It was discovered in 1894, by Lord Rayleigh and Professor Ramsay, by whom later it was estimated as composing about 0.75 per cent. of the atmosphere. Leduc gives its amount as 0.94, and Schloesing as 0.84. It is quite inert, and cannot be made to combine with any other element, although it has been combined by Berthelot with benzene under the influence of electric discharge.

HYDROGEN.

According to the extensive researches of Armand Gautier, hydrogen is present in sea air and other pure air in fairly constant amount—about 0.015 per cent. It is believed to be due to various fermentative processes, and to be contributed also by mineral springs and volcanoes. So far as known, its presence is devoid of sanitary importance.

Other elements, as krypton, neon, and metargon, also discovered by Professor Ramsay, coronium, discovered by Nasini, and several others, are interesting solely from a purely scientific standpoint.

CARBON DIOXIDE (CARBONIC ACID).

All air contains carbon dioxide as a constant constituent. The normal average amount in pure air is but slightly in excess of 3 parts in 10,000, or about 0.03 per cent., and not 4 parts, as commonly is stated. As little as 2.03, and even 1.72, has been observed in the air on mountain-tops, although generally we expect more rather than less than the normal amount at high elevations.

Carbon dioxide is a result of oxidation of organic matter, and owes its presence in the atmosphere to respiration, fermentation, combustion, and chemical action in the soil. An average man exhales about 20 liters in an hour, and very nearly a kilogram in a day; women exhale less, and children and aged persons still less. The amount exhaled is increased by muscular exertion and diminished by rest. Birds send out more in proportion to weight than other animals. The respiration of millions and millions of human beings and animals is constantly throw-

ing into the atmosphere countless tons of the gas; every ton of coal in burning yields more than 67,000 cubic feet; every cubic foot of coal gas yields about double its volume; every pound of candle nearly three times its weight (2.769); every gallon of oil and kerosene, and every piece of wood used as fuel, contributes its proportion. Huge volumes are sent forth continually by the soil air, which contains it in abundance, and by mineral springs, the waters of which contain it under pressure. It has been estimated that, from all sources, 5,000 million tons are discharged annually into the atmosphere. It is slightly more abundant in cities than in the country, and at night than by day. It is highest in amount at a given location during autumn, and lowest in winter. It is more abundant inland than on the coast. It increases somewhat as we ascend from sea-level—according to Schlagintweit, up to 11,000 feet. Its removal from the atmosphere is mostly through the agency of growing vegetation, but materially also by absorption by bodies of water, which, at ordinary temperature and pressure, will take up its own volume of the gas. It has been calculated that the ocean contains about ten times as much as the whole atmosphere. All green plants absorb it by day, and by means of their chlorophyll break it up into carbon and oxygen, the former being used in building tissue, and the latter returned to the air as a waste product. This process of nutrition goes on only under the influence of light, and consequently by day; but there is also a respiratory function that is active both day and night, and has the same effect on air as that of the respiration of animals; namely, the consumption of oxygen and discharge of carbonic acid. But the respiratory process has but a trivial influence in comparison with the chlorophyllian function. It is estimated that an acre of woodland withdraws in one season about four and a half tons, retains more than one and one-fifth tons of carbon, and returns three and a quarter tons of oxygen to the air. The slight increase at night is due supposedly in part to its exhalation by plants in their respiration, and also to currents of soil air, which ascends as soon as the air at the surface becomes colder, and consequently heavier, than itself. During the day, the soil air is colder and remains stationary.

Carbon dioxide is a heavy gas, incapable of supporting combustion or respiration, and serving no useful purpose in animal tissues. It constitutes about 4 per cent. of expired air, in which it is an excretion of the body. It is in itself inert, and incapable of exerting any poisonous action, but will cause asphyxia when present in sufficient amount to interfere with the atmospheric oxygen in the performance of its function.

An atmosphere of respired air, containing 4 per cent., of carbon dioxide and about 16 per cent. of oxygen, will not support life longer than a short time, since the blood cannot get sufficient oxygen for the needs of the cells and tissues, and, in addition, cannot rid itself of its CO_2. Gas exchange between the blood and inspired air depends upon the tension of the gas in both media, and, therefore, as soon as the tension of the CO_2 in the atmosphere exceeds that of the CO_2 of the blood, the

blood corpuscles cannot excrete it, but must retain it. In consequence, asphyxia occurs.

The question as to how much CO_2 is permissible in air, has been answered variously. We assume 3 parts in 10,000 as the normal amount, and all in excess as impurity due to respiration and combustion. A total of 6 or 7 parts in 10,000 is regarded by the best authorities as the permissible limit, and 10 in 10,000 as distinctly harmful. When the amount reaches 10 parts in 10,000, the air begins to be "close"; and when it reaches 15 in 10,000, it is likely to cause headache in those unaccustomed to impure air. In crowded assembly rooms, as churches, theatres, and schools, the amount may reach 100 parts in 10,000; and more than twice as much has been found in a Swiss stable crowded with men and animals. The air of the hall in which the German Public Health Society (Deutscher Verein für öffentliche Gesundheitspflege) met in Nüremberg in October, 1890, contained 24.10 in 10,000 at the beginning of one of the addresses, and 43.20 at its close.

A large amount of carbon dioxide may be present in air without producing any ill effects, if there is plenty of oxygen present. Thus, Regnault and Reiset have proved that animals can live in a mixture of 25 per cent. carbonic acid, 30–40 per cent. oxygen, and nitrogen.

It has been held generally that CO_2 up to 20 : 10,000 is in itself harmless; that the deleterious agents in polluted air are organic matters thrown off by the skin and lungs in company with it; and that it serves as a convenient index of their amount. It has been the custom to say, "The more carbonic acid we find, the more organic matter we infer." These poisonous organic matters, however, though much sought after, have never been isolated, although a number of observers, using faulty methods, have from time to time obtained erroneous results. This subject will be considered farther on.

OZONE.

Ozone is a normal but by no means constant constituent of the air. It is generally absent from the air of large towns and cities, and is almost never present in the air of an inhabited room or near decomposing matter. It is found in minute amounts (maximum, 1 : 700,000) in the open air of the country and sea. It is most abundant at sea and near woods, and somewhat more abundant on mountains than in valleys and on plains. It is more abundant in the morning in the colder months, and in the evening during hot weather; it is more abundant in winter than in summer. It is stated that it is most abundant directly after a thunder-storm, but beyond the fact that it is produced by the passage of the electric spark, there is nothing to substantiate this statement. As a matter of fact, the origin of ozone in the atmosphere is unknown.

Ozone is an allotropic form of oxygen, consisting of molecules containing three atoms of that element. It has been liquefied under great pressure (127 atmospheres), and in that condition, and, indeed, in the

gaseous form, has a deep-blue color. It is produced by the passage of the electric spark, by slow oxidation of phosphorus, and in the electrolysis of water; but, as has been said, its origin as a normal constituent of the atmosphere has not been explained satisfactorily. It has an odor not unlike that of diluted chlorine. It has very strong oxidizing power, much more so than oxygen, which it exercises most actively both on metals and on organic matter; hence its absence from the air of inhabited rooms and of densely populated areas, charged with organic matter and dust of all sorts, is easily explainable. To this property, its diminution in autumn, when decomposition products are generated most actively, may properly be attributed. Its presence in the air of any place is fair evidence of freedom from oxidizable matters.

Ozone has an exceedingly irritating effect on the respiratory mucous membranes, and when inhaled with oxygen in the proportion of 1 part in 240, quickly produces death in animals subjected to it. It is believed to exert a pernicious influence in inflammatory conditions of the lungs and bronchi, even when present in not much more, if any, than the ordinary amount in the atmosphere. We actually know little or nothing of the effects of ozone on the system in the amounts ordinarily present in air, but the absurdity of the expression so often used, that one has "gone to breathe the pure ozone" at a health resort is manifest.

Peroxide of Hydrogen (H_2O_2) is believed to exist in minute traces in the atmosphere, and to exert some influence in the process of oxidation.

AMMONIA.

Ammonia is constantly present in the air in very slight traces. It exists in the free state and in combination as nitrate and carbonate. Daily analysis of the air at Montsouris for five years gave as a mean for ammonia 2.2 milligrams per 100 cubic meters. It proved to be highest in amount in summer and lowest in winter. It is diminished in rainy weather, because it is absorbed by the rain during passage through the atmosphere; it is increased with rising temperature some time after rain has ceased falling. As it is one of the products of decomposition of nitrogenous organic matter, perhaps nowhere more observable than in stables, where it is plainly perceptible to the sense of smell, it is hardly necessary to point out that its sources are various and innumerable.

NITROGEN ACIDS.

Nitrous and nitric acids are also present in small traces, due in part to the union of atmospheric oxygen and nitrogen through the agency of electrical discharges, and in part to the action of ozone on ammonia. Nitric acid is found in comparative abundance in buildings lighted by means of the arc light, but it is not probable that the amount present is of sanitary importance.

AQUEOUS VAPOR.

Aqueous vapor is a normal constituent which occurs in variable amounts, influenced by a number of natural conditions, the chief of which is the temperature. It is an invisible gas, lighter than air and very unequally diffused. Its sources are numerous; some comes from the evaporation of water, some from soil moisture, some from the lungs and skin of animals and man, some from the leaves of growing plants, some from combustion. Indoors, a considerable amount is communicated to the air through the combustion of illuminants.

According to Professor Foster, an adult man gives off, under ordinarily favorable conditions, about 4 pounds of watery vapor from the skin and lungs during twenty-four hours; $2\frac{1}{2}$ pounds by the skin, and the remainder (Pettenkofer and Voit say 10 ounces) by the lungs. An adult healthy tree of fair size gives off an amount which is enormous in comparison. The amount of water exhaled by plants has been estimated by Hellriegel to vary from 250 to 400 times the weight of the dry organic matter formed during the same time, which means that during the growth of each ton of green grass or leaves of any kind, there have been exhaled therefrom many tons of water, and that in the production of each pound of dry matter, an average of 325 pounds of water has been discharged. The evaporation of water from foliage has, among other important functions, that of keeping the temperature below the point where the vital processes would be interfered with.

The amount of aqueous vapor which a volume of air will absorb and retain depends on the temperature. For each degree of temperature, a volume of air can take up a definite amount of vapor, and no more; and when it has taken up this amount it is said to be "saturated." The higher the temperature, the greater the amount it can hold; and hence when a volume of air completely saturated is subjected to a change in temperature, one of two things will occur: if the temperature is increased, it can take up more vapor, and hence is no longer saturated; if it is diminished, the aqueous vapor is in excess of the amount required for saturation at the new temperature, and the excess will be condensed and precipitated as moisture. At 0° C., a volume of air takes up $\frac{1}{160}$ of its weight of aqueous vapor; at 15°, it takes up twice as much; at 30°, four times, at 45°, eight times, and at 60°, sixteen times as much. Thus it appears that, with each increase of 15° C. in temperature, the capacity for aqueous vapor is doubled. At 15° C. (59° F.), a cubic foot of air will hold nearly 6 grains of water vapor; at 30° C (86° F.) it will hold twice as much.

Evaporation cannot go on when the surrounding air is saturated; therefore, the presence of a body of water will add nothing to a saturated atmosphere. But plants and animals can continue to give off the vapor to an already saturated atmosphere, which, however, condenses and deposits the excess at once, perhaps on the very surface where it is originated, as on the leaf of a tree or on the skin of man. The difference between evaporation and transpiration, which is the

proper term for the giving off of vapor by animals and plants, is that the one is merely physical, while the other is a vital process due to the action of living cells.

The rate of elimination of water by the body in a state of rest depends upon the amount of humidity present in the air. Determinations by Rubner and von Lewaschew[1] demonstrated the great influence of humidity in this particular. At 15° C. in moist air, the daily elimination fell to 216 grams, while in dry air at the same temperature it rose to 871. The rate rises with the temperature in both moist and dry air, and the more promptly, the greater the dryness. The outer air contains commonly from 60 to 75 per cent. of the amount necessary for saturation. In some places noted for the dryness of the air, the amount is much below; in others, where the opposite is the case, it is above.

Relative humidity is the degree of approach to saturation at any given temperature. Thus, "relative humidity 80" means that at the observed temperature, the air holds but 80 per cent. of the amount which it can take up. Absolute humidity is the actual weight of moisture in a given air space.

Aqueous vapor exerts a most important influence. By day, it absorbs part of the sun's heat and tempers it; by night, it acts as a protecting blanket to the earth by preventing too great loss of heat by radiation. At night, the earth gives up part of the heat which it has absorbed during the day; and when the air is very dry and the sky very clear, the temperature falls much more than when there is more vapor present to prevent loss by radiation. In the Sahara, after the hottest days, the nights are generally very cool, the temperature falling sometimes 30 to 40 degrees C. in a few hours. At high altitudes also, where the blanket of vapor is thin, the fall in temperature at night is very marked. Absence of aqueous vapor permits the cooling process to begin as soon as the sun gets low, and ice may form in a few hours where, during the day, the sun's heat had been intolerable. This is seen in the great deserts and at high altitudes.

It is noticed commonly that the first frosts of autumn and those which come occasionally in the middle and later parts of spring occur only on very clear nights with low humidity.

An amount of watery vapor approaching saturation gives rise to discomfort, whether the temperature be high or low. The "sticky" days of summer and the "raw" ones of winter owe their disagreeableness to their high relative humidity. In a hot saturated atmosphere, while transpiration can proceed, evaporation cannot, and hence the cooling influence of evaporation is missing. The sweat stays on the skin in the liquid form instead of passing into the air as a vapor, and the word "sticky" becomes singularly appropriate. On the other hand, with low humidity and high temperature, the sweat does not condense and remain on the skin, but passes into the air, and transpiration is not impeded in the lungs. Hence the great bearability of dry heat as

[1] Archiv für Hygiene, XXIX., p. 1.

compared with moist. Saturation at low temperature has as great, if not greater, influence on bodily comfort. It does not follow that since one feels the heat more acutely with high relative humidity, this condition will enable one to withstand the opposite discomfort of cold. Indeed, the reverse is true. At low temperatures, saturated air causes a greater withdrawal of heat than dry air, and intensifies the sensation of cold; for moist air is a much better heat conductor. Cold dry air is much more comfortable than air some degrees warmer but materially moist. In the very cold climate of eastern Siberia, the air is so dry that 50° to 60° below zero F. is no hardship, provided one wears completely dry clothing, while with moist clothing one would perish in a very short time. Some parts of Siberia are both cold and damp, and hence uninhabitable. Atmospheric moisture has, therefore, directly opposite effects; it intensifies the effects of heat and also those of cold.

DUST AND MICRO-ORGANISMS.

Another normal constituent of the atmosphere—one of enormous importance—is dust; normal, because it is everywhere in the atmosphere, and because a perfectly dustless air is an artificial product obtained only with the observance of great care. The individual particles are very small, but at the same time very variable in size, ranging from those plainly discernible to the naked eye, to those of extreme minuteness.

Dust is organic and mineral, and has its origin in countless processes. It includes particles of animal matter, vegetable substances of every kind including bacteria and moulds, sea salt, matters swept from the soil by the action of winds, those discharged by volcanoes,[1] others from manufacturing establishments, from chimneys, and from the millions of meteorites which daily fall from interplanetary space. The ordinary combustion of illuminating gas yields millions and millions of particles of carbon for every individual cubic foot.

Organic dust exists only in the lower strata of the atmosphere, but that of mineral origin is everywhere. Micro-organisms are very abundant in the air of inhabited rooms, and in general in that of towns and cities, less abundant in the country, and least at great heights and at sea. Experiments have shown that at an elevation above 6,300 feet the air is free from them. Pasteur exposed a large number of flasks of broth at an altitude of 6,000 feet, and obtained a growth in but one. Tyndall exposed 27 flasks at 8,000 feet, and got no growth whatever. Dr. Fisher[2] has shown that on the ocean, 120 miles from land, the air is usually free from organisms, and that at lesser distances—90 miles, for example—it contains but few.

The air of cities contains thousands in every cubic meter, against

[1] After the great eruption in Java in 1883, a haze of extremely fine particles of pumice, estimated to be from seven to more than twenty miles above the earth, was visible in all parts of the world for several months.

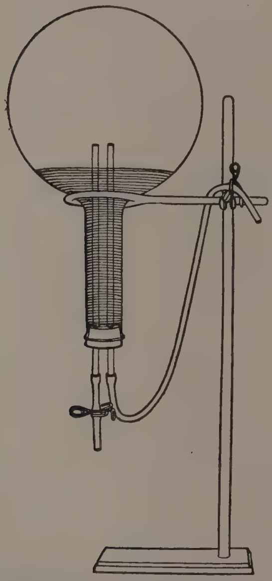
[2] Zeitschrift für Hygiene, I., p. 410.

less than a hundred in the same volume of country air. It has been calculated that, in densely populated places, such as London and Manchester, an individual inhales in the course of an hour upward of 4,000,000 of germs and spores. But this figure is enormously in excess of the figure given by Flügge,[1] who estimates that in seventy years a man may inhale 25,000,000 bacteria, which, he says, is about what one swallows in 25 cc. of ordinary milk.

The number of bacteria in air is influenced very greatly by dry winds and aqueous vapor. The former, sweeping them up from the surface, increases their number; the latter, by condensing on them and on the dust particles to which they adhere, causes them to fall to the ground. They are washed out of the air by rain, and are killed by long exposure to bright sunshine. Moulds, on the other hand, have been observed by Miquel to increase rapidly after a rainstorm, and to be much less affected by winds.

The average number of organisms found at Montsouris in an investigation which lasted six years was 455 per cubic meter. The lowest results were observed in February and the highest in July. During the same period, the number in the air at the center of Paris was 3,910; the smallest figures were yielded in January and the highest in May.

FIG. 8.



Apparatus for demonstrating the relation of dust to rain and fog.

All organisms are less numerous in the air at night, since then there is less mechanical disturbance of the earth's surface.

While the number of bacteria in outdoor air may be fairly high, it should be borne in mind that the majority of them are of the harmless varieties, and that the pathogenic kinds constitute only an infinitesimal proportion.

Dust, as has been said, is of enormous importance. Without it there would be no rain, no fog, no clouds; the air would be saturated with moisture, and every object would be continually wet.

Dust is largely hygroscopic, and, therefore, attracts the watery vapor of the atmosphere, thus becoming the nucleus for a drop of rain or particle of mist. Were it not for its presence in the air, the aqueous vapor would condense without rain on every tree and plant, every rock, every dwelling, every living creature, and, in short, on every object to which air has access.

That atmospheric dust is necessary for the production of rain and fog, may be demonstrated very simply by condensing moisture from a saturated atmosphere through lowering of the temperature, and noting

[1] Grundriss der Hygiene, 1897.

what occurs when dust is present or absent. For this purpose, a simple apparatus such as is shown in Fig. 8 is all that is required. This consists of a large flask fitted with a rubber stopper, through which pass two pieces of glass tubing, to the free ends of which pieces of rubber tubing with pinchcocks are attached. The glass tubes project beyond the shoulder into the body of the flask. If we pour into the flask an amount of water rather more than sufficient to fill the neck when the flask is inverted with the stopper in position, we have the conditions necessary for complete saturation of the confined air with watery vapor. If now we withdraw by suction through one of the rubber tubes a small amount of the contained air, the temperature falls at once; and inasmuch as the air within is already saturated, and since the lowering of the temperature of a saturated atmosphere is accompanied by condensation of part of its moisture, such a condensation occurs within the flask, and is manifested by the formation of a distinct haze which fills the whole air space. If next we restore the original pressure by readmitting sufficient air to abolish the partial vacuum, the mist disappears instantly. The production and dissipation of the mist cloud may be repeated indefinitely so long as nothing is done to remove the dust from the air; but if we wash the air thoroughly by shaking the flask vigorously for a few minutes, and then repeat the experiment, no visible mist is produced.

CARBON MONOXIDE, ETC.

Other matters found in air include, under certain conditions, traces of sulphuretted hydrogen, sulphurous, sulphuric, and hydrochloric acids, carbon disulphide from rubber factories, marsh gas, carbon monoxide from illuminating gas, fumes of zinc, arsenic, and phosphorus, organic vapors from offensive trades, and other gaseous and solid matters too numerous to mention.

The most important of these is **carbon monoxide**, a very powerful poison, often present in the air of inhabited rooms from leaking gas pipes, imperfect combustion of illuminating gas, and defects in heating apparatus fed with coal. It is yielded in great abundance by burning charcoal, and is given off in small amounts from stoves of cast iron, which material in a red-hot condition absorbs it in considerable amounts from burning coal. This was noticed first by Dr. Carret,[1] of Chambéry, who described an outbreak of sickness traced by him to this cause. Later, this property of cast iron was established beyond a doubt by others. Another by no means insignificant source is burning tobacco, 1 gram of which, according to Gréhant,[2] yields 82 cc. of the gas. Its presence in the air of rooms in which smoking is carried on was illustrated by Kunkel,[3] in 1888, before a society of scientists, by exposing a small amount of blood solution to two puffs of tobacco smoke, and demonstrating the absorption of the gas by means of the spectroscope.

[1] Comptes rendus, 1865, p. 793.
[2] Annales d'Hygiène publique, 1879, p. 115.
[3] Sitzungsbericht der physikalisch-medicinische Gesellschaft zu Würzburg, 1888, p. 89.

The most important source of all is illuminating gas, which contains it in varying amounts, according to its mode of manufacture. Under ordinary conditions, the leakage of gas from the mains into the soil and thence into the atmosphere is enormous. Pettenkofer [1] reckoned that in badly jointed systems at least a fifth of the annual output is lost in the ground, and Wasserfuhr [2] has calculated the annual loss in Paris due to leaks as 15,000,000 cubic meters. Leakage occurs from imperfect joints, faulty cocks, and corroded iron pipes. Besides that due to leakage, we have to reckon with that due to imperfect combustion. While an Argand or other burner acting normally gives off no trace of carbon monoxide, a certain proportion of the gas will escape oxidation and mingle with the air of the room together with other impurities, if the gas supply is not properly regulated. The use of gas stoves is responsible for more or less contamination due to imperfect combustion, for when a cold object is put into the flame, the latter is cooled, and part of its carbon monoxide is given off as such. Imperfect combustion of kerosene is still another source which should not be overlooked, for a smoking lamp exerts a very decided influence on the respirability of the air of a room, aside from the discomfort caused by the particles of soot.

Less than 0.25 per cent. by volume in the air will cause poisoning, and but 1 per cent. is rapidly fatal to animal life, owing to the fact that it unites very readily with the hæmoglobin of the blood corpuscles, forming a stable chemical compound, carboxyhæmoglobin, which will neither take up and carry oxygen to the tissues nor promote the elimination of carbon dioxide. As a consequence, asphyxia occurs.

In fatal cases of poisoning, carbon monoxide produces a rapid parenchymatous degeneration of the liver, kidneys, spleen, and heart.

Carbon monoxide has been proved by L. de Saint Martin [3] to be present in minute amounts in the blood of animals living in cities. Nicloux [4] has gone farther, and demonstrated its existence in that of animals in the country, and, indeed, in about the same amounts (0.16 volume per cent.). Nicloux finds by experiment that it is not derived from the air, but is developed directly in the system, and that its amount is diminished by bringing about slight asphyxiation. Potain and Drouin [5] have shown that, at ordinary temperatures, it is oxidized gradually to carbon dioxide.

Contamination of the air of dwellings with gas from leaking street mains is quite common, and fatal results are not infrequent, the gas travelling through the soil for considerable distances and being drawn up through cellars by the force of aspiration brought into play by the difference between internal and external temperatures. Many cases of fatal poisoning have been recorded in which the gas was aspirated through the soil for more than a hundred feet. Such accidents are

[1] Ueber die Vergiftung mit Leuchtgas. Nord und Sud, January, 1884.
[2] Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, XVII., 1885, p. 309.
[3] Comptes rendus, CXXVI., p. 1036.
[4] Ibidem, CXXVI., pp. 1526, 1595.
[5] Ibidem, CXXVI., p. 938.

naturally more likely to occur in streets which, being well paved, present an obstacle to the escape of the gas upward. The odorous constituents of the gas serve a very useful purpose in pointing out the danger, but sometimes they are held back by the earth and cannot perform that office.

Dr. J. S. Haldane has pointed out that air vitiated by gas combustion to such an extent as to show 30 parts of CO_2 in 10,000 will contain about 1 part of SO_2 per 500,000, and that this amount is sufficient to cause marked discomfort. The air of a room lighted with oil was not unpleasant, except for the heat, when the CO_2 content rose to 75; but when gas was burned it was distinctly unpleasant when the CO_2 rose to 40 in 10,000.

"SEWER GAS."

Another impurity is what commonly but improperly is called "sewer gas." This is simply sewer air which may be more or less foul by reason of containing the emanations of sewage matters. Its chemical composition depends upon the extent to which the gases of decomposition are generated, and upon the rate of ventilation. It may be almost as pure as the outside air; it may be as rich in carbon dioxide as the air of badly ventilated rooms; and it may be much worse. From 10 to 30 volumes of CO_2 in 10,000 are found quite commonly. Dr. W. J. Russell found as high as 51 volumes in 10,000 in the air of one of the London sewers, and Letheby as high as 53.2 in that of another, while in an unventilated sewer in Paris as high as 340 volumes have been reported. Sulphuretted hydrogen and ammonium sulphide are ordinarily present in small amounts or mere traces, and may be wholly absent; but in old unventilated sewers, they may be present in notable amounts. The highest recorded, 299 volumes in 10,000, was found by Parent-Duchatelet in an old choked sewer in Paris. Marsh gas, ammonia and compound ammonias, and other gaseous products of decomposition of organic matter, may be present in variable amounts, according to circumstances.

Sewer air contains micro-organisms and animal and vegetable débris, just as does the outer air; but, as a matter of fact, the number of bacteria is invariably small, and they are often wholly absent. This was shown first in 1883 by Miquel, whose results have been corroborated by those of a number of other investigators, including Carnelly and Haldane, Laws and Andrews, and Percy Frankland. The first mentioned conducted a most elaborate chemical and bacteriological examination of sewer air, and proved that from both points of view it compares favorably with the air of schools and small dwellings, and that bacteriologically it is, indeed, far superior. It contains fewer organisms than the air of the streets above or of any kind of dwelling, and such as are present come entirely or chiefly from the outer air, and not from the sewage.

Laws and Andrews arrived at the same conclusions after a similar research. In each sample of sewage examined, *B. coli communis* was

found in numbers varying from 20,000 to 200,000 per cc., and closely allied species in even greater abundance; but neither the one nor any of the others was found in the many samples of air examined. They found, farther, that the number of organisms existing in sewer air depends entirely upon the number present in the outside air in the immediate vicinity, and that while sewage bacteria are largely of the liquefying varieties, such are practically absent in the air.

The chief importance of "sewer gas" lies not in its power to produce disease, but in its capacity for being the vehicle for odors which make the air disagreeable, but not necessarily dangerous to health, except that appetite and digestion, and hence general nutrition, may be interfered with.

As a matter of fact, sewer air has served for a long time as a most convenient scapegoat in investigations of the cause and spread of outbreaks of typhoid fever and other infectious diseases, and as a most useful aid in explaining obscure questions of various sorts. Many believers in the sewer-air theory of dissemination of typhoid fever hold that the coarser dust particles carry the germs on their surface, and may be blown about through considerable distances before the organisms lose their vitality; but the great objection to this explanation is that in sewers and cesspools the typhoid bacillus is destroyed speedily by other organisms, and that, even though it be present in an active state in liquid sewage, it is extremely unlikely that it will be released therefrom into the air. No ordinary stirring up of the water will throw the germs into the air; although, according to the researches of Frankland,[1] the bursting of gas bubbles generated by decomposition will throw into the air traces of chemical salts which have been mixed and dissolved in the sewage, and in the same way may throw out bacteria as well. But it has been shown by Nägeli that bacteria cannot be given off from moist surfaces.

Another explanation, offered by Dr. C. R. C. Tichbourne,[2] is that the disease germs are scattered into the air by the fermenting sewage, and carried by a mist formed when the warm sewer air, saturated with moisture, meets the colder external air at the points where ventilating outlets are placed. Then each minute droplet of mist, carrying one or more microbes, is transported through longer or shorter distances in the air, perhaps into dwellings, and eventually, by the influence of the heat of the sun or by other natural agency, becomes dissipated as vapor, and leaves the organisms suspended in the atmosphere.

The majority and the best of the German investigators, as Flügge, Rubner, Gärtner, Soyka, Prausnitz, and others, maintain that sewer air and sewer gases are incapable of conveying the germs of typhoid fever and other infective diseases. It is true that some of the gases given off in the putrefactive processes which go on in sewers are more or less poisonous, but whether they are capable of produc-

[1] Proceedings of the Royal Society, 1879.
[2] Dublin Journal of Medical Sciences, July, 1897.

ing injurious effects depends very much on the amount inhaled and on the degree of concentration. In any event, they are certainly incapable of producing any infective disease in the absence of the specific germ.

In any well-constructed and properly ventilated sewer, no great amount of putrefaction will go on, since the sewage matters soon pass on and are discharged ; consequently not much gas will be evolved, and, with proper ventilation, whatever is evolved, is soon dissipated in the outer air. Offensive gases and odors are much more likely to be given off by unclean unventilated house-plumbing than by well-built sewers.

It is asserted commonly that the inhalation of small amounts of this air will produce headache, anæmia, loss of appetite, sore throat, albuminuria, diarrhœa, and other symptoms, and that it may be the exciting or auxiliary cause of typhoid fever, measles, diphtheria, scarlet fever, dysentery, and other infective diseases. But in the cases which are accepted as proving the causal relation, inference has taken the place of proof, no other means of infection being ascertainable. In not a single case has the supposed relation been demonstrated bacteriologically.

In answer to the well-known stubborn fact that the workmen employed in all the large systems of sewerage—men whose occupation involves the daily and constant inhalation not of traces, but of large volumes, of sewer air—are as a class unusually healthy and strong, with a high mean age at death and a low death-rate, it is asserted that they become immunized by daily contact, and thus escape. If we accept this theory, however, we should go farther, and say that large doses are a benefit in that they confer immunity, and that, therefore, all precautions against the admission of sewer air to the air of dwellings are misdirected, and should be abandoned.

The air of properly constructed sewers is in constant motion, brought about by differences in temperature and mechanically through influx of sewage. During the colder months, the temperature within the sewer is higher than that of the air above, and it is influenced materially by the fact that the entering sewage is largely warm ; therefore, sewer air tends to rise and escape through the openings in the man-hole covers. During the warm season, the natural interchange is much lessened, since then the conditions as to temperature are reversed. At night, however, at all seasons, the temperature of the air of the sewer is higher than that of the atmosphere above, and thus ventilation goes on by natural laws the year round. Much air is displaced by the entering sewage ; in fact, disregarding the effect produced by the warmth of the sewage, for every cubic foot of sewage which enters, a cubic foot of air is forced out, and as the sewage is discharged, more air enters to take its place.

Owing to the prevailing belief in the noxious character of sewer air, it was formerly the custom to place baskets of charcoal in the outlet shafts of the man-holes, but as this material loses its absorptive property with access of moisture, the plan was abandoned. It was also

regarded as an advantage to connect the sewer with chimneys, which act as ventilators, but in the light of farther knowledge and because of excessive action, that method of ventilation fell into disuse.

ORGANIC MATTERS.

Among other impurities given off to the air, the organic matters from the processes of the body are, in a way, of considerable importance. These include particles of epithelium, the constituents of sweat (butyric, capric, capronic, and caprylic acids, lactate, butyrate, and other salts of ammonium), and volatile matters from foul mouths, decaying teeth, and the digestive tract, and excrementitious matters deposited on unclean clothing. In addition to these, it has been asserted that other matters of a poisonous character are given off in the process of respiration, which matters will be referred to later on in the discussion of the effects of impure air on health. That the air of inhabited confined spaces may contain organic animal matter, is apparent to the senses when one enters such an atmosphere from one not thus contaminated.

Effects of Vitiated Air.

The effects of foul air on the system are of great importance, and vary in degree within very wide limits. For proper aëration of the blood, it is necessary that the oxygen of the air shall be present in the normal proportion in the free state, and not in chemical union with carbon as a waste product. Farther, it is necessary for the proper excretion of the carbon dioxide of the blood that the difference in the tension of that gas in the air and of that in the blood shall be as wide as possible; that is to say, the less the amount of carbon dioxide in the inspired air, the greater the facility with which the blood can disengage that which it carries to the lungs. Any interference with this most important function of the body must have an injurious effect on the general health, and it is accepted generally that impurity of the air is, without doubt, the most important of the predisposing causes of disease.

It is well known that, other conditions being equal, in proportion as a people are drawn to employments indoors, the disease-rate and death-rate are increased. This is particularly true as regards phthisis, which is preëminently associated with overcrowding.

Overcrowding means the association of two or more people in a space so confined as to preclude the admission of a constant supply of fresh air sufficient in amount to maintain a proper dilution of their excretory products and a normal supply of free oxygen. It was recognized long ago as a most important factor in the production of a high death-rate among occupants of crowded jails, barracks, and hospitals; and experience has demonstrated repeatedly that increase in space allowance is followed always by decrease in sickness- and death-rates. At one time, for example, the English army averaged 11.9 deaths per

1,000 men annually, from phthisis alone; more efficient barrack ventilation and increase of average air space caused immediate improvement, and the phthisis-rate fell gradually to 1.2 per 1,000. The same general result has been observed in the armies of France, Russia, Germany, and Belgium.

What is true of overcrowding applies not alone to human beings, but to animals as well, and it is a well-known fact that crowded stables show high mortality among cows and horses. It has such a remarkable influence on egg production and growth of fowls that practical poultrymen are exceedingly careful on this point.

The immediate effects of inhalation of impure air are discomfort and oppression, which may amount to headache, dizziness, faintness, and even nausea. Continued exposure is likely to bring about a gradual impairment of health, shown by pallor, languor, anæmia, skin troubles, loss of appetite, and diminished power of resistance to the exciting causes of disease, and this is especially true of those whose daily work is carried on in crowded spaces.

It is customary to cite as extreme cases of overcrowding and its effects, the Black Hole of Calcutta, the ship *Londonderry*, and the prison at Austerlitz; but the conditions that obtained in each of these instances were most unusual, and the cases are of historical rather than sanitary interest, since the confining of a number of persons in a space from which air is practically excluded can have but one outcome.

The Black Hole of Calcutta is the name applied to the military prison of Fort William, where, in June, 1756, Surajah Dowlah confined 146 persons over night in a space of less than 5,900 cubic feet, with two small windows in one side. Within an hour, all broke out in a profuse sweat, and were tortured with thirst and difficult breathing; in three and a half hours, a majority were delirious, and when the place was opened in the morning, 123 of the prisoners were found dead.

In the case of the *Londonderry*, which, in December, 1848, left Sligo for Liverpool and ran into a storm, 200 steerage passengers were confined over night in a space 18 by 11 by 7 feet, with no means of ventilation. In the morning, when they were released, it was found that over 70 had expired.

In the other extreme case, that at Austerlitz, 300 captured soldiers were confined in a small cellar, and within a few hours all but 40 were dead.

To what one or more conditions of impure air are the ordinary effects due? We have seen that CO_2 is in itself not an active poison, and that its action is to interfere with the proper oxygenation of the blood within the lungs. The aqueous vapor of respiration and from the skin, and that produced in the combustion of illuminating material, constitutes an important part of a vitiated atmosphere, and is responsible for at least a part of the discomfort produced; but it is also true that a deficiency in watery vapor in the air of well-ventilated rooms has equal or greater disadvantages, as will appear in the consideration of Ventilation.

Concerning the effect of usual amounts of ordinary dust in inhabited rooms, there is little to be said. The micro-organisms, most of which are non-pathogenic, vary in number with efficiency of ventilation. In pure air, the bacteria and moulds approximate each other in number; but in vitiated air, the bacteria increase in number, while the moulds are much less affected. The experiments of Carnelly, Haldane, and Anderson showed a progressive increase in both bacteria and moulds with diminished ventilation. Thus,

Character of air space.	Number organisms in 10 L. air.		Ratio of moulds to bacteria.
	Moulds.	Bacteria.	
External air	2	6	1:3
4-roomed houses	4	85	1:21
2-roomed houses	22	430	1:20
1-roomed houses	12	580	1:48

The increase in bacteria is not due to respiration, though a diminution in their number might be thus explained; for the great majority of inhaled bacteria are filtered out by the nose, and the expired air is almost completely free from germs, although they may be thrown out in the act of coughing or sneezing.

Investigation thus far has not proved that the bacteria of infection are commonly introduced into the system through the medium of respired air.

As has been mentioned, it is held by many that the effects of vitiated air are not due to carbon dioxide, but to the organic matters and aqueous vapor given off by the lungs and skin, and that these are estimated conveniently by determining the amount of carbon dioxide with which they are discharged. It is said also that, while considerable carbon dioxide escapes even under the most imperfect system of ventilation, the organic matters and watery vapor do not so readily pass out, but are deposited on walls, furniture, hangings, and clothing, where they putrefy and become offensive. As proof of this, is cited the fact that a room in which a person has slept without adequate ventilation has an unpleasant smell in the morning, and that this persists even after prolonged airing.

Brown-Séquard and d'Arsonval, in 1888, obtained from condensation of the aqueous vapor of men and animals a liquid which, injected into rabbits, caused death with greater or less rapidity, according to the size of the dose. They believed the toxic element to be of the nature of a volatile alkaloid, and that it was exhaled dissolved in the aqueous vapor of the breath. In the same year, Wurtz, reporting a similar research, claimed to have found a toxic substance.

Merkel,[1] in 1892, claimed to have obtained positive results, and concluded that respired air from persons in health contains a minute quantity of a volatile organic base, which is poisonous when free, but innoc-

[1] Archiv für Hygiene, XV., p. 1.

uous after contact with an acid. Dr. Sivierato[1] collected the aqueous vapor of the breath of persons suffering from diseases of respiration, both with and without fever, of persons with no respiratory disease, but with fever, and of persons in health, and injected it into rabbits. That from those with respiratory diseases produced fever and diminished reflexes lasting three to six days; that from cases of fever with no respiratory disease caused little or no disturbance; and that from persons in health produced no results whatever.

Formánek[2] concluded, after much study, that no poisonous substance originates in the lungs; that the ammonia sometimes found is not a product of metabolism, but of decomposition in the mouth cavity (carious teeth, etc.) and in the trachea and lungs after tracheotomy, and in pulmonary tuberculosis; that, in the experiments which led to the theory of an unknown alkaloid, ammonia was used, and might have caused the observed effects; and that the results of overcrowding cannot be due to any one cause.

Many other experimenters, French, German, Italian, American, and English, working along the same lines, but with extra precautions to exclude matters from the nose and mouth, have failed to obtain toxic effects from the condensed vapor; others have demonstrated that the lungs exhale no organic matter except in minute amounts, and that these have no poisonous influence.

Arloing pursued the subject further, in the belief that the constituents of the sweat are concerned in the harmful effects. He soaked the underclothes of a man who had spent a long evening in dancing, and injected the watery extract into dogs and rabbits. From the fact that the animals showed various evidence of intoxication and died he concluded that sweat is toxic. Experiments in the author's laboratory, however, with sweat obtained directly from well-scrubbed forearms and injected in considerable amounts into rabbits and other animals yielded negative results. Sweat vaporized in small confined spaces was equally innocent of harmful results to men and animals exposed thereto. At present the weight of evidence leads to the conclusion that the injurious action of vitiated air is due to the diminution of oxygen and to the increase of carbon dioxide, both of which factors, alone or together, interfere with the intake of oxygen and the excretion of carbon dioxide from the lungs. Yet, diminution in oxygen, which even in very crowded rooms does not proceed very far, is met by increase in the respiratory function, which, however, cannot increase the difference between the tension of the carbon dioxide of the air and of the blood. Not even in very imperfectly ventilated mines does the oxygen fall much below 20 per cent. by volume, and thus we see that the whole range of fluctuation in the oxygen of pure and of very foul air is but little more than 1 volume per cent.

Smith and Haldane[3] have shown that in a leaden chamber containing

[1] Archives Italiennes de Biologie, 1895.
[2] Archiv für Hygiene, XXXVIII. (1900), p. 1.
[3] Journal of Pathology and Bacteriology, I., 1892.

air which had suffered but slight diminution in oxygen, but which contained 384 parts of carbon dioxide in 10,000, two men suffered from headache immediately on entering.

As a rule, vitiated air is associated with high temperature and saturation with aqueous vapor, which latter interferes with evaporation from the skin. Less often it is associated with low temperature, and with this condition comes an increased demand for oxygen to meet the requirements of the oxidation processes.

It seems probable that where the carbon dioxide is not present in any great excess, and the oxygen is not markedly deficient, the conclusion arrived at by Drs. Weir Mitchell, Billings, and Bergey is true; namely, that the discomfort suffered is due largely and chiefly to heat and disagreeable odors arising from the occupants in various ways: from bad breath, unclean skin, unclean clothes, sweat, and gases from the bowels. Such may induce very disagreeable sensations, amounting even to nausea, in those who are not habituated to such influences; but, on the other hand, those who are accustomed to such air notice no discomfort.

Disagreeable smells do not act directly as a cause of specific disease, but appear to have an influence on the appetite, and hence on the general well-being of persons not accustomed to them. Much is due also to the imagination; a disagreeable smell from a source known to be clean (chemicals, for instance) has not ordinarily as much influence as another of equally offensive character supposed to be from filth. It seems probable also that there is much to learn concerning the real effects of disagreeable smells, and that they may be more extensive than we now commonly believe; but in order to determine this, we shall need methods which will reveal the nature of the odoriferous substances and make their isolation possible.

Other causes of discomfort may be sought for in the presence of traces of carbon monoxide from heating apparatus or incomplete combustion of illuminating gas, and in excessive dryness of the air due to furnace or steam heat.

It should not be overlooked that impure air may affect the vitality and bactericidal power of the cells of the air-passages and of the alimentary tract, and thus lessen the power to resist the action of infective material.

The Air as a Carrier of Infection.

On the agency of air in spreading infectious matter, much has been said and written, and much careful research has been conducted, but the conclusions reached are by no means in agreement or conclusive. It is conceded generally that pathogenic organisms in the air are adherent to particles of dust of various kinds, and that their retention of virulence depends upon the amount of hygroscopic moisture with which they are associated. The conditions favorable to their continuance as living organisms are naturally more likely to obtain in indoor air, with imperfect ventilation, than in the outer air, where they are diluted and blown about and exposed to the disinfectant action of the direct

rays of the sun. Indoors or outdoors, the more they are protected by hygroscopic dust particles, the longer they will retain the moisture which is essential to their viability. It appears, too, that, conditions being equal, certain micro-organisms retain vitality longer than others, some being but slightly, others very tenacious of life.

With regard to the transmission of pulmonary tuberculosis through the air, it should be said that while there can be no doubt that this disease is connected preëminently with overcrowding and vitiated air, there is a very decided difference of opinion as to the method of conveyance, some contending that dust, and others that tuberculous material, thrown into the air in coughing, speaking, and sneezing, is the vehicle.

Buchner has found *B. tuberculosis* in an active state in the dust of a room a year after the death of its occupant from the disease. G. Cornet[1] demonstrated its presence in more than a third of 147 samples of dust collected in hospitals and other public institutions, and in private houses inhabited by phthisical persons, and succeeded later in producing the disease in 46 out of 48 guinea-pigs exposed to air containing dust from dried tuberculous sputum. Some of the animals were placed 8 inches from a glass vessel containing dried pulverized sputum from an advanced case; others were placed on shelves 8 to 28 inches from the floor of a room, on the carpet of which, sputum, mixed with dust, had been spread and dried and, at the end of two days, stirred up by sweeping; others were allowed to stay in the room without disturbance of the dust.

Klein obtained positive results with guinea-pigs placed in the ventilating shaft of a consumptives' hospital; but Heron[2] obtained but 2.7 per cent. of positive results in 74 guinea-pigs inoculated with dust from the ventilating shaft of the London Hospital for Diseases of the Chest; and Kirchner[3] got but 1 positive result out of 16 pigs inoculated with the dust from a military hospital. Flügge, on the other hand, was wholly unsuccessful in inducing the disease in guinea-pigs exposed to such dust; and concluded that the transmission from one person to another is chiefly by means of the finest droplets thrown into the air in speaking, coughing, and sneezing. From later experiments, conducted under his supervision by Laschtschenko, Heymann, Sticher, and Beninde,[4] he concluded that in rooms in which tuberculous sputum is dried on the floor or other places, and where the air is filled with coarse dust through dry cleaning and air currents, or, as in railway cars, by continual mechanical jarring, infection may arise; and that, under these conditions, long-continued exposure offers a certain degree of probability of infection. Therefore, dry cleaning is to be avoided in rooms in which consumptives are employed with others, and the rooms should not be occupied so long as the air is perceptibly dusty. The great possibility of infection through matters thrown off in coughing and sneez-

[1] Zeitschrift für Hygeine, V., p. 191. [2] The Lancet, January 6, 1894.
[3] Zeitschrift für Hygiene und Infectionskrankheiten, XIX., p. 153.
[4] Ibidem, XXX., p. 107.

ing is insisted upon as of paramount importance. This danger is to be prevented by requiring the person coughing to hold a handkerchief or the hand before the mouth during the act, and by the avoidance on the part of others of approaching within a meter.

Answering Flügge, Cornet[1] contends that the number of bacilli thrown into the air during the act of coughing must be extremely small. He caused 18 consumptives to hold dishes before the mouth while coughing, and obtained 2 positive results therefrom on inoculation into guinea-pigs; repeating the test with 15 others, he got none; but Heymann[2] was more successful, for glass plates exposed in the immediate vicinity of coughing consumptives, confined for an hour and a half in a glass cabinet of three cubic meters' capacity, were proved to have become contaminated by the specific organism. The plates were rubbed up with small amounts of broth, which was then injected intraperitoneally into guinea-pigs, mostly with positive results.

Experiments conducted by Königer[3] confirm Flügge in his estimate of the danger of transmission by droplets. In order to give the expelled droplets a character which would admit of their being traced, he rinsed his mouth with liquid rich in *B. prodigiosus* or *B. mycoides*, or with very dilute caustic soda, and, in order to trace them, he exposed Petri dishes and glass plates coated with phenolphthalein, which agent, turning pink in contact with an alkali, would show not only the number of droplets, but their size as well. It was found that no droplets are thrown out in ordinary exhalation nor in vowel formation, but with consonants, as *t*, *k*, and *p*, the number is very great, and is largely dependent upon the amount of force with which the air under pressure in the mouth cavity is released in their formation, and, therefore, upon the manner of pronouncing. Loudness and rapidity of speech have but little influence; whispering may, indeed, under some conditions, cause a greater number of droplets than loud speech. Even with subdued speech and a quiet atmosphere, it was found that the organisms expelled reached the most distant parts of the room, which was more than 20 feet in width, and in all directions. They were found to remain in suspension in the air not longer than an hour, and it was noticed that they fell upon the plates in groups, sometimes as many as 40 close together, which suggests that they fall not as dry dust particles, but that the droplets themselves, with their contained or adherent organisms, are deposited. In coughing and sneezing, more droplets are expelled than in speaking, and they are projected to a greater distance, because of the greater force engaged. The precautions recommended apply not alone in tuberculosis, but also in diphtheria, whooping-cough, and other diseases in which the respective specific organisms are found in the air-passages.

Hutchison[4] found that bacteria, sprayed in minute droplets upon

[1] Berliner klinische Wochenschrift, May 13, 1899.
[2] Zeitschrift für Hygiene und Infectionskrankheiten, XXXVIII. (1901), p. 21.
[3] Ibidem, XXXIV. (1900), p. 119.
[4] Ibidem, XXXVI. (1901), p. 223.

objects, perish in a short time, the main factor in their destruction being the influence of sunlight. Sprayed directly into the air, most of them were found to have become deposited within a half hour, when the air of the room was allowed to remain undisturbed, but numbers of them were kept in suspension for considerable periods by slight unavoidable air currents in the lower strata. He showed that, with favoring air currents, the suspended bacteria may be conducted through very narrow crevices, as into closed bureau drawers, and from one room to another through keyholes and cracks. While the danger of disseminating bacteria by walking over an infected floor was found to be slight, those thrown up by the elastic rebound of the boards failing to infect plates suspended 4 inches above them, ordinary sweeping was found to contaminate the atmosphere throughout its whole extent, even to the ceiling, thus confirming Flügge's statement as to the undesirability of dry cleaning.

Closely similar results were obtained by Kirstein,[1] who concludes that ordinary air currents cannot detach living organisms from surfaces upon which they have been deposited and become dried, but concedes that, when the bacteria are sprayed upon fine dust particles, they may easily be borne about in the air. Yet how slight the danger of this method of infection is, so far at least as typhoid fever is concerned, is shown by the marked rapidity with which the typhoid organisms die when sent forth in the form of spray. Other non-spore-builders, sprayed into the air, retained their vitality for only a comparatively short time, because of the influence of light and air; and he believes that the marked sensitiveness of the tubercle bacillus to the influence of light makes early destruction of this organism most probable when it is thrown into the air in minute droplets, and that thus may be explained the fact that, even in consumptive wards, in which there is, without doubt, a constant discharge of bacilli into the air, attempts to detect living organisms in the dust, etc., fail, excepting in those cases in which the sputum itself has, through lack of care, become disseminated.

Positive results of examination of droplets expelled by consumptive patients during coughing have been recorded by Curry,[2] Boston,[3] and others. Curry experimented with 12 patients, who coughed toward plates suspended from 1 to 3 feet distant; he found the bacilli in the larger droplets expelled by half the subjects. Boston, observing fine droplets being ejected from the mouth of a patient with advanced disease in each act of coughing, concluded that such constant spraying at the table and elsewhere might afford an explanation why patients in the early stage of the disease did not do well in the institution where his observations were made, in which every possible attention is given to ventilation, light, and disinfection of sputum. By means of a simple device, the spray sent out by 50 patients was collected, and then sub-

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXV. (1900), p. 123.
[2] Boston Medical and Surgical Journal, October 13,1898.
[3] Journal of the American Medical Association, Sept., 14, 1901.

jected to examination for the specific organism, which was found in 76 per cent. of the cases. The smallest number found in any specimen was 4, and in fully a third the bacilli were very numerous.

Ravenel's[1] experiments with tuberculous cows have proved that they, too, send forth the bacilli in great numbers in the act of coughing.

Experiments conducted at the Adirondack Cottage Sanitarium by Dr. I. H. Hance,[2] for the purpose of determining the degree of danger of infection when all possible sanitary measures for disinfection of sputum are enforced, support the view that dust in the air is of secondary importance, but that, where carelessness in this regard obtains, the danger is a real one. A complete examination was made of the group of buildings, some of which had been occupied by consumptives for eleven years. Dust was collected from places most likely to be infected, and with it 81 guinea-pigs were inoculated. Four inoculated with dust from the infirmary (a building where all the acutely sick are sent), and from the main building (in which are a parlor, sitting-room and library), died of other infections on the third to the sixth day. Five of the ten inoculated with dust from the oldest cottage, which was occupied by a man who had been complained of for promiscuous spitting, became tuberculous. Those inoculated with the dust from the other buildings gave negative results. During eleven years, not one of the 20 to 25 attendants employed had developed the disease.

As to typhoid fever, too, opinions are at variance. Dr. John Brownlee reported before the Glasgow Philosophical Society an experiment proving that the specific bacilli can live in ordinary dust. Buchner is of the opinion that neither typhoid nor other fevers can thus be spread.

Perhaps the most extensive research on the subject of transmission of this and other diseases is that conducted by Dr. Eduardo Germano.[3] In his experiments, he used various kinds of dust and dirt, and from his results, he concludes that the typhoid germ is unable to withstand complete drying, and hence cannot be transmitted to man through dust sufficiently dry to be disseminated by air currents. Experiment showed that the germ can live for a long time in moist surroundings, even in an apparently dry condition, that is, when adherent to or encompassed by matters which contain a certain amount of moisture, such as clothing, particles of dirt, and fecal filth. Most of the bacilli die as drying progresses, but some are more or less resistant, though not necessarily dangerous on admission to air currents, since then complete drying and consequent death occur. They are dangerous only in case of introduction into the system through contact with the fingers, food, or eating utensils.

[1] University Medical Magazine, November, 1900.
[2] Medical Record, December 28, 1895.
[3] Zeitschrift für Hygiene und Infectionskrankheiten, XXIV., p. 403; XXV., p. 439; XXVI., pp. 66 and 273.

With regard to diphtheria, Germano found that the bacillus withstands long drying in membranes, tissues, and dust, even when the drying process is assisted by sulphuric acid; and that its resistance is greater according to the amount of enveloping material which retards oxidation. When completely dry, it preserves its virulence up to the time it dies. Hence his belief that this disease may be disseminated by air currents.

With regard to pneumonia, erysipelas, and other streptococcus infections, Germano finds that the resistance of the organism to the drying process is always high, though it varies with the method followed and the nature of the enveloping material, and may persist a number of months. Transmission through the air is extremely probable. The diplococci, in general, bear drying for a long time; some varieties live longer when dried than if moist, and some possess but little resistance; but the rapidity of the drying process with medium temperature does not affect the result. He found that the cholera organism retains its virulence only so long as it remains moist, and dies quickly on drying, particularly if the process is hastened. He concluded that dissemination by air is most highly improbable.

Germano's work with the plague bacillus confirms the results announced by Kitasato and Wilm. This organism does not withstand drying, but lives a long time in a moist condition. It remains active fairly long when dried on cloth, because then complete drying requires a long time, and thus may be explained the danger of infection recognized to exist in infected clothing.

Germano's experiments with the diplococcus of epidemic cerebrospinal meningitis agree in results with those of Jäger, who found the organism in an active condition in a handkerchief six weeks after use by a patient sick with the disease. Germano shows that it belongs to the class of bacteria which oppose the greatest possible resistance to drying, whether the process is slow or quick, and whether assisted by the action of sulphuric acid; and concludes that it may without difficulty enter the air in the form of dust, and thus spread the infection. This view is supported by Buchanan,[1] who argues from the fact that, of 60 cases which came under his observation, 57 were in men who followed occupations in which they were exposed to dust, the specific organisms are thus conveyed.

Dr. Max Neisser,[2] working in the same line as Germano, with an apparatus of his own design, which maintains a constant aspiration current of dusty infected air, disagrees as to the pneumococcus, inasmuch as, while mice, inoculated with infected dust, died from the infection without exception, 24 others, inoculated with the dust after it had been sent through the apparatus in a current of air, gave absolutely negative results. His experiments with various organisms led him to the conclusion that dust infection is impossible with the organisms of diphtheria, typhoid fever, cholera, plague, and pneumonia, but

[1] British Medical Journal, September 14, 1901.
[2] Zeitschrift für Hygiene und Infectionskrankheiten, XXVI., p. 175.

possible with *Staphylococcus pyogenes aureus*, *B. pyocyaneus*, *B. anthracis*, *B. tuberculosis*, and meningococcus.

Neisser's conclusions, so far as they relate to diphtheria, are opposed to the results obtained by Richardière and Tollemer,[1] who made a series of examinations of the air of diphtheria wards of the Hôpital Trousseau. In one set of experiments, the wards had not been disinfected for several weeks; and in another, the examinations were made after disinfection had been carried out. The results showed that active diphtheria bacilli were present in the air which had not undergone disinfection. The bacteriological tests were controlled by inoculation experiments with animals.

With regard to the possibility of spreading cholera germs through the agency of moving air, Dr. N. William[2] has reported that, while that means has been regarded as most favorable, in actual experiment it fails. Mixed with dry dust, the germs live but a short time, and perish more quickly when a current of air is conducted through the dust. When the dust is distributed through large volumes of air, the germs die rapidly, and when the impregnated dust is let fall upon a suitable culture, only a very small proportion of living organisms can be found. In other words, cholera germs, adherent to dust particles floating in and moved about by air, do not retain their activity for any length of time nor through any considerable distance.

The experiments of Honsell[3] indicate that the cholera organism finds no favoring conditions for its passage into the air from its situation in privy vaults.

The subject of danger of cholera infection by dust from baled rags was considered thoroughly at the Dresden Cholera Conference, and it was found impossible then to quote a single case in which infection could be traced to this source.

According to Dr. E. W. Hope,[4] atmospheric dust is largely responsible for the spread of infantile diarrhœa in cities and large towns, where, from unavoidable causes, the air becomes more or less laden with filth. He presents evidence of the association of rainfall and its attendant cleansing of the atmosphere with diminished mortality from choleraic diarrhœa, as follows:

Period.	Average rainfall June to September.	Conditions.	Annual average of deaths from diarrhœa during third quarter of year.
6 years	13.8 inches	Average wet summers.	373
14 "	10.9 "	Average dry summers.	573
Extreme years.			
1891	16.0 "	Wettest summer.	203
1895	7.7 "	Driest summer.	819

[1] Gazette des Maladies infantiles, No. 10, 1899.
[2] Zeitschrift für Hygiene und Infectionskrankheiten, XV. (1893), p. 166.
[3] Arbeiten aus dem patholog-anatomischen Institut zu Tübingen, 1896.
[4] Public Health, July, 1899.

Influence of Fog.

Dust and moisture together in the form of fog affect the health of large communities in a marked degree. In a still air nearly or completely saturated with aqueous vapor and containing ordinary dust and smoke, a fall in temperature causes each particle of dust and soot to become the nucleus of a minute droplet of condensed moisture. These countless droplets in a state of suspension form a more or less dense blanket of fog, which impedes dispersion of the impurities given off by natural processes and as products of combustion. While ordinary country and seashore fogs are not known to exert deleterious effects, in smoky cities, like London, the case is quite different.

It is a well-recognized fact that, during periods of heavy fogs in manufacturing centers, the morbidity and mortality from respiratory disease are increased very greatly, and that, as the atmosphere clears, a sharp decline follows. In London, for example, the usual death-rate from all causes has been known to become almost doubled during a fortnight of continued dense, smoky fog, and then to return to its normal figure with the advent of clear weather, the increase being due particularly to bronchitis and other affections of the respiratory tract, attributed to the irritating influence of the finely divided particles of soot and the acids which accompany them.

During the prevalence of thick fogs, the air being necessarily in a stagnant condition, it has been observed that the carbon dioxide content increases progressively. During one such period following bright weather, the air of London acquired, in four days, three and a half times its normal content of this gas.

The importance of smoke, both as a promoter of disease and on account of its corrosive and disfiguring action on buildings, and also on account of the obstruction of light, has led to much legislation and to the exercise of inventive genius for devising means for the prevention of its discharge in objectionable amounts into the atmosphere of cities. Many patents have been granted for smoke-consuming devices, the majority of which have been found to work unsatisfactorily. The most effective invention, which gives promise of solving the problem most completely, is one which has been brought to the attention of the Department of State by Consul General Mason.[1] This process consists in distributing heated and slightly compressed air through hollow grate bars to the whole lower surface of the furnace. Not only is practically perfect combustion attained, but immense saving of expense is possible, since what are ordinarily unsalable low-grade coals can be employed to greatest advantage.

Examination of Air.

For all practical purposes, the examination of air may be restricted to the determination of the amounts of aqueous vapor and carbon dioxide. The essential element, oxygen, fluctuates within such very

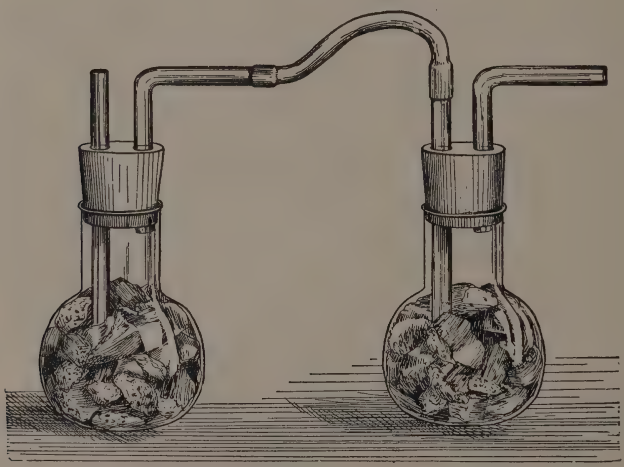
[1] Consular Reports, 1899, p. 491.

narrow limits that its estimation is a matter of purely scientific interest, and, moreover, the process is one which demands a much higher degree of manipulative skill than is possessed by those to whom the task of making sanitary examinations ordinarily falls. The chief constituent, nitrogen, is practically constant in amount, and its determination would serve no useful purpose. Whatever is the cause of the deleterious effects of an atmosphere vitiated by respiration, whether it be carbon dioxide or the organic matters given off by the body, this at least is certain, that the amount of carbon dioxide serves as an index of impurity, and that the amount of aqueous vapor is of considerable sanitary importance. In special cases, it is important to look for that most dangerous contamination, carbon monoxide, which, coming even in very small amounts from leaking gas pipes and other sources, exerts a decidedly deleterious influence. In the minds of many, the test for ozone is also of importance.

In addition to chemical analysis, the determination of the amount of dust and the number and varieties of micro-organisms present may be of interest and importance.

Determination of Aqueous Vapor.—As has been stated above, a volume of air at a given temperature can hold a definite amount of moisture, and no more, and when this amount is present the air is said

FIG. 9.



Apparatus for direct determination of moisture.

to be saturated. The amount which a volume of air contains constitutes its absolute humidity, and the difference between this and the amount which it is possible for it to hold is known as its saturation deficiency. The ratio which its absolute humidity bears to its possible content is known as its relative humidity.

Direct Determination of Moisture by Weighing.—Prepare two wide-mouthed flasks of about 150 cc. capacity in the following manner:

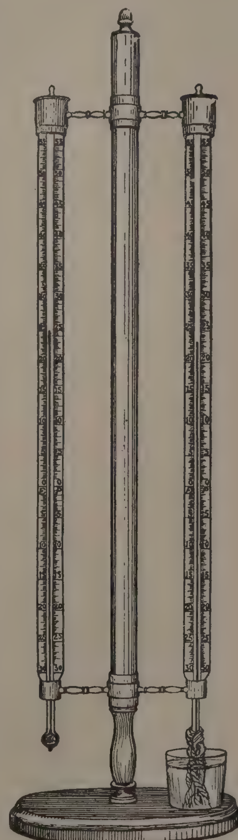
Provide each with a tightly fitting rubber stopper with two perforations, through which are inserted two pieces of glass tubing bent at a right angle. One of these reaches to the bottom of the flask, and serves as an inlet; the other extends only a short distance below the stopper, and serves as an outlet. Fill the flasks with small pieces of pumice which have been heated to a high temperature over a Bunsen burner, dropped while hot into concentrated sulphuric acid, removed therefrom, and quickly drained. The two flasks thus filled, and with stoppers tightly inserted, are then to be connected by means of a short piece of rubber tubing, the inlet of one joining the outlet of the other. They are then weighed. The flask with the free outlet tube is now to be connected with an aspirator, by means of which from 20 to 50 liters of air are drawn through. As the air comes in contact with the pumice saturated with sulphuric acid, its moisture is absorbed and retained. At the expiration of the aspirating process, the flasks are disconnected from the aspirator and again weighed. The increase in weight represents the amount of moisture in the volume of air used. The apparatus is shown in Fig. 9. Knowing the temperature of the air, one can then easily determine the relative humidity by reference to the table below, which shows the maximum humidity possible at different temperatures.

TABLE OF MAXIMUM WATER CAPACITY FOR TEN LITERS OF AIR.

Temperature centigrade.	Corresponding degrees F.	Grams.	Temperature centigrade.	Corresponding degrees F.	Grams.
—10	14.0	0.021	13	55.4	0.113
— 8	17.6	0.027	14	57.2	0.120
— 6	21.2	0.032	15	59.0	0.128
— 4	24.8	0.038	16	60.8	0.136
— 2	28.4	0.044	17	62.6	0.145
0	32.0	0.049	18	64.4	0.151
1	33.8	0.052	19	66.2	0.162
2	35.6	0.056	20	68.0	0.172
3	37.4	0.060	21	69.8	0.182
4	39.2	0.064	22	71.6	0.193
5	41.0	0.068	23	73.4	0.204
6	42.8	0.073	24	75.2	0.215
7	44.6	0.077	25	77.0	0.229
8	46.4	0.081	26	78.8	0.242
9	48.2	0.088	27	80.6	0.256
10	50.0	0.094	28	82.4	0.270
11	51.8	0.100	29	84.2	0.286
12	53.6	0.106	30	86.0	0.301

Determination of Relative Humidity by the wet and dry Thermometer Bulbs. This instrument, which is known also as the psychrometer, consists of a pair of accurate thermometers on an upright support. The bulb of one is free; that of the other is covered with a

FIG. 10.



Psychrometer.

layer of muslin kept moistened by means of a piece of wicking which dips into a small vessel of water beneath. (See Fig. 10.) In a saturated atmosphere, no evaporation can occur from the wet muslin; but in one not saturated, the process goes on with varying rapidity. Evaporation is a process which requires heat and causes a lowering of the temperature of the moist surface; the more rapid its rate, the greater the abstraction of heat. The drier the atmosphere, the greater the rate of evaporation, and, therefore, the greater the fall in temperature. If the instrument is placed in a saturated atmosphere, the two thermometers will give the same readings; but in one not saturated, the wet thermometer will fall gradually until the temperature of the surface of its bulb is nearly as low as that of the dew-point; that is, falls to that point at which air at the indicated temperature is so saturated that a farther lowering would be followed by condensation of moisture. As a matter of fact, the wet thermometer does not fall so far in a quiet air, since its bulb becomes surrounded by a layer of stagnant saturated air, and receives more or less heat from the surrounding warmer atmosphere. Again, in a saturated atmosphere, the wet thermometer may stand slightly higher than the dry one, owing to the fact that its covering protects it from loss of heat by radiation.

GLAISHER'S TABLE.

Reading of dry bulb thermometer.	Factor.	Reading of dry bulb thermometer.	Factor.	Reading of dry bulb thermometer.	Factor.
10	8.78	41	2.26	71	1.76
11	8.78	42	2.23	72	1.75
12	8.78	43	2.20	73	1.74
13	8.77	44	2.18	74	1.73
14	8.76	45	2.16	75	1.72
15	8.75	46	2.14	76	1.71
16	8.70	47	2.12	77	1.70
17	8.62	48	2.10	78	1.69
18	8.50	49	2.08	79	1.69
19	8.34	50	2.06	80	1.68
20	8.14	51	2.04	81	1.68
21	7.88	52	2.02	82	1.67
22	7.60	53	2.00	83	1.67
23	7.28	54	1.98	84	1.66
24	6.92	55	1.96	85	1.65
25	6.53	56	1.94	86	1.65
26	6.08	57	1.92	87	1.64
27	5.61	58	1.90	88	1.64
28	5.12	59	1.89	89	1.63
29	4.63	60	1.88	90	1.63
30	4.15	61	1.87	91	1.62
31	3.60	62	1.86	92	1.62
32	3.32	63	1.85	93	1.61
33	3.01	64	1.83	94	1.60
34	2.77	65	1.82	95	1.60
35	2.60	66	1.81	96	1.59
36	2.50	67	1.80	97	1.59
37	2.42	68	1.79	98	1.58
38	2.36	69	1.78	99	1.58
39	2.32	70	1.77	100	1.57
40	2.29				

For the purpose for which it is intended, the instrument is exposed until the wet thermometer ceases to fall, and then the reading of both is noted. From these data, with the assistance of Glaisher's factors (see table on page 254), the dew-point is easily calculated in the following manner: Multiply the difference in the two readings by the factor opposite the figure in the table corresponding to the temperature of the dry bulb, and subtract the product from this temperature.

TABLE OF TENSIONS.

Temperature. Fahrenheit.	Corresponding degrees C.	Tension in inches of mercury.	Tension in mm.	Temperature. Fahrenheit.	Corresponding degrees C.	Tension in inches of mercury.	Tension in mm.
1°	—17.2°	0.046	1.17	51°	10.6°	0.374	9.50
2	—16.7	0.048	1.22	52	11.1	0.388	9.86
3	—16.1	0.05	1.27	53	11.7	0.403	10.24
4	—15.6	0.052	1.32	54	12.2	0.418	10.62
5	—15.0	0.054	1.37	55	12.8	0.433	11.00
6	—14.4	0.057	1.45	56	13.3	0.449	11.40
7	—13.9	0.060	1.52	57	13.9	0.465	11.81
8	—13.3	0.062	1.57	58	14.4	0.482	12.24
9	—12.8	0.065	1.65	59	15.0	0.500	12.70
10	—12.2	0.068	1.73	60	15.6	0.518	13.16
11	—11.7	0.071	1.80	61	16.1	0.537	13.64
12	—11.1	0.074	1.88	62	16.7	0.556	14.12
13	—10.6	0.078	1.98	63	17.2	0.576	14.63
14	—10.0	0.082	2.08	64	17.8	0.596	15.14
15	— 9.4	0.086	2.18	65	18.3	0.617	15.67
16	— 8.9	0.090	2.28	66	18.9	0.639	16.23
17	— 8.3	0.094	2.38	67	19.4	0.661	16.79
18	— 7.8	0.098	2.49	68	20.0	0.684	17.37
19	— 7.2	0.103	2.62	69	20.6	0.708	17.98
20	— 6.7	0.108	2.74	70	21.1	0.733	18.62
21	— 6.1	0.113	2.87	71	21.7	0.759	19.28
22	— 5.6	0.118	3.00	72	22.2	0.785	19.94
23	— 5.0	0.123	3.12	73	22.8	0.812	20.62
24	— 4.4	0.129	3.28	74	23.3	0.840	21.34
25	— 3.9	0.135	3.43	75	23.9	0.868	22.05
26	— 3.3	0.141	3.58	76	24.4	0.897	22.78
27	— 2.8	0.147	3.73	77	25.0	0.927	23.55
28	— 2.2	0.153	3.89	78	25.6	0.958	24.33
29	— 1.7	0.160	4.06	79	26.1	0.990	25.15
30	— 1.1	0.167	4.24	80	26.7	1.023	25.98
31	— 0.6	0.174	4.41	81	27.2	1.057	26.85
32	— 0.0	0.181	4.60	82	27.8	1.092	27.74
33	+ 0.6	0.188	4.78	83	28.3	1.128	28.65
34	1.1	0.196	4.98	84	28.9	1.165	29.59
35	1.7	0.204	5.18	85	29.4	1.203	30.55
36	2.2	0.212	5.38	86	30.0	1.242	31.55
37	2.8	0.220	5.58	87	30.6	1.282	33.56
38	3.3	0.229	5.82	88	31.1	1.323	33.60
39	3.9	0.238	6.04	89	31.7	1.366	34.69
40	4.4	0.247	6.27	90	32.2	1.410	35.81
41	5.0	0.257	6.53	91	32.8	1.455	36.95
42	5.6	0.267	6.78	92	33.3	1.501	38.12
43	6.1	0.277	7.04	93	33.9	1.548	39.31
44	6.7	0.288	7.32	94	34.4	1.596	40.53
45	7.2	0.299	7.59	95	35.0	1.646	41.80
46	7.8	0.311	7.90	96	35.6	1.697	43.09
47	8.3	0.323	8.20	97	36.1	1.749	44.42
48	8.9	0.335	8.51	98	36.7	1.802	45.77
49	9.4	0.348	8.84	99	37.2	1.856	47.14
50	10.0	0.361	9.17	100	37.8	1.911	48.54

Having now determined the dew-point, the next step is to ascertain the elastic tension of the vapor present in the air, that is, the tension of the dew-point, and the tension of that necessary for saturation at the temperature of the dry bulb, which data can be obtained by reference to the table on page 255.

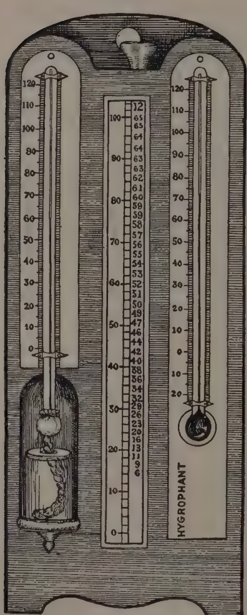
From these several data the relative humidity is calculated as follows: Divide the tension of the dew-point by that of saturation at the actual temperature, and multiply by 100.

Example:

$$\begin{aligned}
&\text{Reading of dry bulb} &&= 67^\circ\\
&\text{Reading of wet bulb} &&= 62^\circ\\
&\text{Dew point} &&= 67-(5\times 1.80) = 67-9 = 58^\circ\\
&\text{Relative humidity} &&= \frac{0.482}{0.661}\times 100 = 72.92 \text{ per cent.}
\end{aligned}$$

More accurate determination may be made by employing the "whirled" or "sling" thermometers. These are fastened to a string of such a length that the distance from the bulbs to the held end is exactly a meter. In use, they are whirled in a horizontal plane 100 times at the rate of one revolution per second. By their use, the errors mentioned as likely to occur when the observations are made in still air are eliminated. For all practical purposes, the use of the thermometers in the ordinary way gives sufficiently accurate results.

Fig. 11.



Hygrophant.

In making determinations out of doors when the temperature is below the freezing-point, the wick may be dispensed with, and the bulb is then wetted by dipping it into water, the excess being removed by means of filter-paper or common blotting-paper, or water may be applied with a camel's-hair pencil. Below the freezing-point, however, the relative humidity is of little hygienic interest, since the amount of moisture which air then can contain is but slight.

A very convenient instrument for quick approximate determinations without the necessity of tables and computation is known as the hygrophant of Winlock and Huddleston. It consists of a pair of thermometers and a cylinder, upon which is inscribed a series of 22 columns of figures numbered from 1 to 22, any one of which may, by a turn of a knob, be brought into apposition with a fixed scale on the casing. (See Fig. 11.) To ascertain the relative humidity, note the difference in the readings of the thermometers, turn the cylinder, until the column having at its top the number corresponding to the difference appears opposite the scale,

and read the figures opposite the number corresponding to the temperature of the wet bulb.

Example:

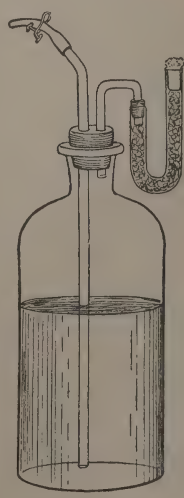
Reading of dry bulb	= 72°
Reading of wet bulb	= 60°
Difference	= 12°

The cylinder is turned until column 12 appears. Opposite 60 of the scale, the reading is 46; and this is approximately the percentage of saturation present.

Determination of Carbon Dioxide.—For the collection of samples of air for this determination, it is well to provide a number of bottles of about a gallon capacity. These should, first of all, be measured very carefully. This may be done by filling them with ice water and noting the number of cc. required, or by determining by means of platform scales sensitive to 5 grams the difference between their weights empty and filled. It is well to place a distinguishing number and the figures denoting its capacity on each bottle, either on a label, or, better, by means of a writing diamond. When used, the bottle should be perfectly clean and dry.

When it is necessary to employ the same bottle again, time being an object, the drying process is hastened very much by washing first with water, then with a little alcohol to remove the small amount of water which will not drain away, and, finally, with a little ether for the removal of the residuum of alcohol. The small amount of adherent ether may then be removed by blowing a current of air into the bottle by means of a bellows. A number of tightly fitting rubber caps should be provided in place of corks or rubber stoppers, though if these are not at hand, the latter may be used; but note should be made of the volume of air which they displace when they are inserted.

FIG. 12.



Bottle for barium hydrate.

Solutions Required.—1. SOLUTION OF BARIUM HYDRATE.—Dissolve about 4.5 grams of barium hydrate and 0.5 of barium chloride in a liter of distilled water which previously has been boiled, in order to expel any carbon dioxide which it may contain. It is well to prepare an amount sufficient for future needs, say 4 liters, and to keep it in a bottle such as is shown in Fig. 12. This is provided with a rubber stopper with two perforations, through one of which a bent tube, reaching to the bottom, and intended for withdrawal of the reagent, is inserted. Through the other is carried a tube extending only into the neck, and communicating at its outer extremity with a U-tube filled with pieces of pumice soaked while hot in a strong solution of caustic potash. The delivery tube carries at its outer

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end a piece of closely fitting rubber tubing, which is kept closed by means of a pinchcock.

In withdrawing the reagent for use, a 100 cc. pipette is inserted into the free end of the rubber tube, suction is applied, and the pinchcock is opened. When the pipette is filled to the mark, the pressure is removed from the pinchcock and the pipette released. As the reagent is withdrawn, air flows in through the other opening, and is robbed of its carbon dioxide by contact with the caustic potash with which the pumice has been charged. This reagent is used for the absorption of the carbon dioxide contained in the sample of air under examination. The reaction is expressed by the following formula:

$$BaO_2H_2+CO_2=BaCO_3+H_2O.$$

The function of the barium chloride is explained below.

2. Standard Solution of Oxalic Acid.—Dissolve 2.808 grams of pure oxalic acid in a liter of distilled water. One cc. of this solution is equivalent to 0.5 cc. of carbon dioxide; that is to say, will neutralize the same amount of barium hydrate as will combine with carbon dioxide to form barium carbonate.

3. Solution of Phenolphthalein.—Dissolve 0.5 gram of phenolphthalein in 100 cc. of alcohol. This solution is used as an "indicator" of alkalinity.

Process of Analysis.—The process of analysis depends upon the fact that when a volume of the barium hydrate solution is brought into contact with carbon dioxide, its alkalinity is diminished by the formation of barium carbonate, which is a neutral body. The greater the amount of carbon dioxide to which it is exposed, the greater will be the reduction of its alkaline strength. A preliminary determination of the amount of oxalic acid solution which 100 cc. of the reagent will neutralize is made by titrating 25 cc. contained in an Erlenmeyer flask and colored by means of a few drops of the phenolphthalein solution, and multiplying the result by 4. After the reagent has been subjected to the influence of the gas in the air sample, a similar determination is made. The difference between the two results, divided by 2, indicates the number of cc. of carbon dioxide present in the amount of air employed.

The sample of air is obtained in the following manner: One of the bottles above mentioned is placed in the situation from which the air is to be obtained, and its air content is displaced by means of a bellows provided at its outlet with a rubber tube of sufficient length to reach nearly or quite to the bottom. A half minute's pumping is sufficient to insure that the original air is replaced by that under observation. One is sometimes admonished to be careful not to breathe in the direction of the mouth of the bottle, but this is an unnecessary precaution, since the current issuing from the bottle is much too powerful to admit of the entrance of any air except that propelled by the bellows. A much more and very necessary precaution to be observed is that the operator shall not allow his breath to reach the inlet holes of the bel-

lows. After a half minute's pumping, the rubber cap is affixed, and the bottle may then be carried to the laboratory, or, better, the treatment of the contained air may be proceeded with on the spot. Another method of collecting the sample is often recommended in place of the one described. It consists in filling the bottle with water and emptying it where the air is to be taken. By this process, the space originally occupied by water is filled with air, but the method is objectionable in that the water cannot drain away completely, and that that which remains serves to dilute, slightly it is true, the charge of barium hydrate next to be introduced, and thus brings in an error at the very outset.

Next, 100 cc. of the barium hydrate solution are introduced by drawing aside the edge of the rubber cap and inserting, into the opening so made, the point of the filled pipette, and allowing its contents to flow unaided into the bottle. The beginner will often incline inadvertently to gain time, and assist the emptying of the pipette, by blowing into it, thereby vitiating his results with the impurities of his own respiration. As soon as the pipette is emptied, it is withdrawn and the edge of the cap is replaced. The bottle is then shaken thoroughly for about ten minutes, care being observed not to wet the cap, since in that event some of the reagent may escape by capillary attraction. At the end of that time it may be assumed that all of the contained carbon dioxide has been brought into contact with and absorbed by the barium hydrate, which is then to be poured quickly from the bottle through a fairly large funnel into a glass-stoppered bottle of rather more than 100 cc. capacity. The solution, which is now more or less turbid from the presence of barium carbonate, is allowed to stand until, through settling of this substance, the supernatant liquid is clear. Three successive portions of 25 cc. each are next to be withdrawn by means of a pipette of the proper size, and, after addition of the indicator, titrated in Erlenmeyer flasks with the standard oxalic acid solution until the pink color caused by the former is made to disappear. So long as any color remains, one knows that barium still exists in the form of hydrate, and that the contents of the flask are still alkaline, for phenolphthalein gives a pink tinge only in the presence of the alkalies. When the pink color disappears, the process is finished, and the reading of the burette is noted. The three portions of 25 cc. each are titrated in turn, and the mean of the results is multiplied by 4. The difference between this product and the figure obtained in the preliminary test of the strength of the reagent, divided by 2, indicates the number of cc. of carbon dioxide in the volume of air taken for analysis.

In filling the 25 cc. pipette from the bottle containing the used reagent, great care should be observed not to stir up the sediment of barium carbonate. To perform the operation properly, it is necessary to insert the point of the pipette well below the surface, and to fill it up to the mark, or just beyond it, by one uninterrupted act of suction. If one stops to regain breath, part of the liquid already within the

pipette will escape downward during the interval with sufficient force to stir up the sediment. When the pipette is filled, the point of the tongue should be applied to its upper end, and the tip should then be withdrawn from the bottle. Then by placing the end of the forefinger over the opening of the tip of the pipette, the escape of its contents is prevented, while the forefinger of the other hand is replacing the point of the tongue. The reason for such careful avoidance of stirring up the sediment is that the presence of barium carbonate introduces a slight error in the titration. The slight excess of oxalic acid present when the color of the phenolphthalein is discharged attacks the suspended barium carbonate, forming barium oxalate and setting free the combined carbon dioxide. Thus :

$$H_2C_2O_4 + BaCO_3 = BaC_2O_4 + H_2O + CO_2.$$

The free carbon dioxide then attacks more of the carbonate and forms barium bicarbonate, which, being soluble and of alkaline reaction, causes the pink color to reappear.

$$\begin{array}{l} CO_2\langle^{OH}_{} \\ \qquad > Ba = BaH_2(CO_3)_2. \\ CO_2\langle_{OH} \end{array}$$

The reason for adding barium chloride in making the barium hydrate solution is that most barium hydrate contains, in addition to small amounts of carbonate, traces either of caustic soda or of caustic potash. When either of these substances is brought into contact with barium chloride, mutual decomposition occurs, and we have as results barium hydrate and sodium (or potassium) chloride. If the impurity were disregarded, it would cause errors, as shown below. The barium hydrate solution when titrated with oxalic acid would behave according to the following formula:

$$\underset{\text{(Barium hydrate)}}{BaO_2H_2} + \underset{\text{(Barium carbonate)}}{BaCO_3} + \underset{\text{(Sodium hydrate)}}{2NaOH} + \underset{\text{(Oxalic acid)}}{2H_2C_2O_4} = \underset{\text{(Barium oxalate)}}{BaC_2O_4} + BaCO_3 + \underset{\text{(Sodium oxalate)}}{Na_2C_2O_4} + 4H_2O$$

In practice a very slight excess of oxalic acid is also present, and the reaction then proceeds still farther. The sodium oxalate attacks the barium carbonate, forming barium oxalate and sodium carbonate. Thus

$$Na_2C_2O_4 + BaCO_3 = BaC_2O_4 + Na_2CO_3.$$

Next, the sodium carbonate neutralizes the traces of free oxalic acid, and any surplus causes a reappearance of the pink color and necessitates farther addition of oxalic acid. This causes the formation of more sodium oxalate, which in its turn attacks another portion of the barium carbonate, with the same results as before; and so the cycle continues until the last trace of suspended carbonate is decomposed. If the hydrate contains no impurities, the addition of chloride is unnecessary.

Corrections.—In figuring the results of the determination, certain corrections are necessary. First, the volume of the barium hydrate used (100 cc.) must be subtracted from the capacity of the bottle, since its introduction displaces an equal volume of air; and next, allowances must be made for any departure from standard temperature and barometric pressure, since the capacity of the sample bottle is reckoned for air at 0° C. and 760 mm. pressure. In order to make the necessary corrections for temperature and pressure, the thermometer and barometer should be noted at the time of taking the sample.

In determining the amount of correction, we are guided by two physical laws: that for each degree of temperature, air expands a constant fraction of its own volume (Law of Charles); and that the volume of a gas is inversely proportionate to the pressure (Law of Boyle). For each degree centigrade above or below 0° C., air expands or contracts 0.0036648 of its volume; and this figure is known as the coefficient of expansion for centigrade degrees. For each degree Fahrenheit above or below 32°, air expands or contracts 0.002036 of its volume; and this is known as the coefficient of expansion for Fahrenheit degrees. Thus, 1 liter of air, heated to 40° C., will expand to $1 + (40 \times 0.0036648)$, which equals 1.146592 liters; or heated to 104° F. (104° F. = 40° C.), it will expand to $1 + (72 \times 0.002036)$, which equals 1.146492, as before. Again, the same volume cooled to $-15°$ C., will contract to $1 - (15 \times 0.0036648)$, or 945 cc.; or cooled to 5° F. (5° F. = 15°C.), it will become $1 - (27 \times 0.002036)$ or 945 cc., as before. So an apparent volume of 1,000 cc. at any temperature above freezing is in reality a smaller volume expanded to that size; and at any temperature below, is a larger volume brought to that size by contraction.

To correct volume for temperature, we must divide the apparent volume by 1 plus the product of 0.0036648 times the number of degrees away from 0° C., or in case of temperatures below freezing, by 1 minus that amount. If the Fahrenheit scale is used, the appropriate coefficient and factors must be substituted. Thus we may employ a set of formulæ as follows:

For temperatures above 0° C. . . . . $V = \dfrac{V'}{1 + 0.0036648.t° \text{ C.}}$

For temperatures below 0° C. . . . . $V = \dfrac{V'}{1 - 0.0036648.t° \text{ C.}}$

For temperatures above 32° F. . . . $V = \dfrac{V'}{1 + 0.002036\ (t° \text{ F.} - 32)}$

For temperatures below 32° F. . . . $V = \dfrac{V'}{1 - 0.002036\ (32 - t° \text{ F.})}$

In the above, V = correct volume.
V' = apparent volume.

Inasmuch as volume is inversely proportionate to pressure, the true volume at any observed pressure is obtained by multiplying the apparent volume by the barometric pressure expressed in millimeters

or inches, and dividing the product by 760 or by 29.92, as the case may be. We may use, then, this formula:

$$V = \frac{V' \times B}{760}.$$

Applying it, we find that an apparent volume of 1,000 cc. at 750 mm. becomes

$$\frac{1{,}000 \times 750}{760} = 987 \text{ cc.}$$

or using the other scale, the barometer standing at 29.53 inches (29.53 in., 750 mm.), it becomes

$$\frac{1{,}000 \times 29.53}{29.92} = 987 \text{ cc.}$$

If the barometer reads higher than the standard pressure, the true volume will be greater than the apparent. Thus, suppose the pressure to be 30.22 inches, then 1,000 cc. will represent

$$\frac{1{,}000 \times 30.22}{29.92} = 1{,}010 \text{ cc.}$$

Instead of going through two separate calculations, we may make both corrections at once by means of one formula which is a combination of the two kinds already used. For temperatures above 0° C. the correct volume is obtained by means of the following:

$$V = \frac{V' \times B}{(1 + 0.0036648 . t^\circ)\ 760}.$$

By changing the plus sign to minus, the formula is adapted to temperatures below freezing. If the Fahrenheit thermometer is used, and the barometric pressure is expressed in inches, the formula is as follows:

$$V = \frac{V' \times B}{[1 + 0.002036\ (t^\circ \text{ F.} - 32)]\ 29.92}.$$

and if the temperature is below 32°, it must be changed to

$$V = \frac{V' \times B}{[1 - 0.002036\ (32 - t^\circ \text{ F.})]\ 29.92}.$$

In these formulæ:

V = correct volume.
V' = apparent volume.
B = barometric pressure.
t° = temperature.

In order to avoid the tedious process of multiplication and division which the working of these formulæ involves, recourse may be had to the admirable tables of Dr. Walter Hesse,[1] wherein can be found the correction to be made for all temperatures between — 2° and 30° C. and for all pressures between 680 and 770 mm., by simple reference to the proper column.

[1] Tabellen zur Reduction eines Gasvolumens auf 0° und 760 mm. Brunswick, 1879.

For all practical purposes, the coefficients of expansion may be shortened to 0.00366 and 0.002, thus avoiding much figuring which has very little influence on the end results.

Example of Method of Reckoning CO_2.—Capacity of sample bottle, 3,885 cc. 25 cc. of barium hydrate solution require 21 cc. of standard solution of oxalic acid, hence 100 cc. = 84 cc. After contact, 25 cc. require 17.2 cc.; 100 cc. require 68.8 cc.

Difference in oxalic acid required = 84 — 68.8 = 15.2 cc.

1 cc. of oxalic acid solution = 0.5 cc. of CO_2; hence, 15.2 cc. = 7.6 cc. of CO_2.

The air in the bottle contained, therefore, 7.6 cc. of CO_2.

Determination of volume of air taken:

Capacity of bottle	= 3,885
Amount of barium solution	= 100
Apparent volume of air	= 3,785
Observed barometric pressure	= 29.60 inches.
Observed temperature	= 65° F.

$$V = \frac{3{,}785 \times 29.60}{[1 + (0.002036 \times 33)] \times 29.92} = \frac{112{,}036}{1.067188 \times 29.92} = \frac{112{,}036}{31.93} =$$

3,509 cc. = actual air volume examined.

Then 3,509 cc. of air contain 7.6 cc. of CO_2. It being customary to express results in parts per 10,000, this rate is determined as follows:

$$3{,}509 : 7.6 = 10{,}000 : x \quad x = 21.66.$$

Hence the air contains 21.66 volumes of CO_2 in 10,000.

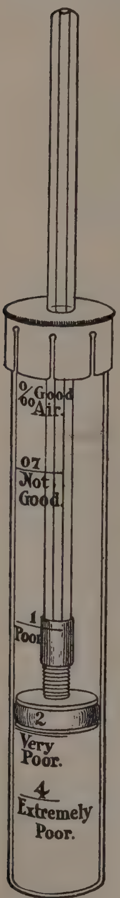
Determination of CO_2 by Wolpert's Method.—This process is designed for what may be called roughly approximate work in testing the air of school rooms and similarly crowded spaces. It requires no chemical training on the part of the operator, and for practical purposes gives fairly satisfactory results, indicating that the air is good, fair, poor, or very bad. The apparatus consists of a graduated glass cylinder with a movable piston reaching to the bottom and kept in proper position by a metallic cap, through the center of which the shaft protrudes. The shaft is a glass tube of narrow caliber, open at both ends. The reagent used is a standard solution of alkali, colored with phenolphthalein.

In making a test, the piston is removed and 2 cc. of the solution are introduced into the cylinder by means of a pipette. The piston is replaced and pressed down until all air is expelled through the shaft and the liquid appears within the bore. The piston is then drawn up until its lower edge is opposite the first mark, and in the process the space so made is filled with air which enters through the shaft. The apparatus is now shaken vigorously for one minute. If the liquid becomes colorless, it is proof that the air of the room is bad. If, on the other hand, the color persists, the piston is raised to the next graduation, and the shaking is renewed for another minute. If the reagent still retains color, the piston is raised further and more air is admitted. The process is continued until repeated additions of air and renewed

shakings cause the color to be discharged. At this point, the reading of the scale indicates the character of the air. The greater the amount of air required for complete decolorization, the less the relative amount of impurity. The apparatus is shown in Fig. 13.

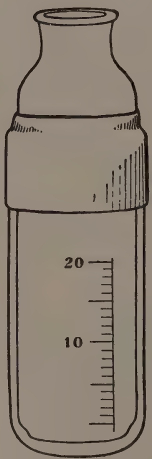
Determination by Fitz's Method.—A modification of this process, giving results which are in close agreement with parallel analyses by the Pettenkofer method above described, has been devised by Dr. G. W. Fitz.[1] The apparatus is very simple, and consists of a small cylinder of glass with a rounded bottom, and a smaller open one which slips into the other through a collar of rubber tubing which makes a tight joint. As the inner cylinder is drawn out, air enters through its upper end, and its amount is measured by the graduations on the outer tube, the lower margin of the inner tube serving as an index. (See Fig. 14.)

FIG. 13.



Wolpert's air tester.

FIG. 14.



Fitz's air tester.

The reagent used is a 1 per cent. solution of lime water made in the following manner. About 95 cc. of water containing a few drops of phenolphthalein solution are neutralized by the addition, drop by drop, of lime water, which causes a pink color that at first disappears on shaking. As soon as a faint tinge persists, the complete neutralization of the carbon dioxide of the water is evident. One cc. of saturated lime water is next added, and the whole is then made up to 100 cc. The solution should be made as needed, since it retains its full strength but about twelve hours.

In making a test, 10 cc. are introduced into the outer cylinder; the inner one is inserted as far as it will go and then raised to the 10 cc. mark on the scale, which means the presence of 20 cc. of air, since the tube itself contains 10 cc. The apparatus is then closed by applying the end of the forefinger, and shaken vigorously thirty times. If the pink color persists, the inner cylinder is pushed to the bottom and then drawn up again, and the operation is repeated until the color disappears. At this point, the amount of air used is noted, and by reference to a table, the number of parts per 10,000 is ascertained.[2] Dr. Fitz asserts that, in the hands of an ordinarily careful man, the process is accurate within 1 part of CO_2 in 10,000.

[1] Journal of the Massachusetts Association of Boards of Health IX., p. 5.
[2] The apparatus and complete directions for use are obtainable of the Knott Apparatus Company, Boston.

This is substantiated by Professor L. P. Kinnicutt,[1] of the Worcester Polytechnic Institute, who has employed the process himself and controlled its use by others with parallel analyses by the Pettenkofer method.

Determination of Carbon Monoxide.—While a number of processes have been devised for the detection and determination of carbon monoxide, none has been discovered as yet that is wholly satisfactory for other than qualitative work. The gas may be detected qualitatively by exposing water containing a small amount of fresh normal blood to the air under examination, and then examining the same with the spectroscope. If no carbon monoxide is present in the air, the characteristic absorption bands of oxyhæmoglobin, shown by the spectroscope, are changed to a single band in the space between on the addition of a reducing agent, such as ammonium sulphide. If, however, the gas is present, no change occurs.

The test is applied in the following manner: A few drops of blood well diluted with water are exposed to the air in a jar, and brought into intimate contact by vigorous shaking. A few drops of ammonium sulphide are next added, and the mixture is again well shaken. If on spectroscopic examination but a single band is observed, the absence of the gas in amount equal to 3 parts per 10,000 may be inferred, for this is the limit of delicacy claimed. If, however, the characteristic two bands of oxyhæmoglobin appear, the presence of the impurity to that extent is proved, since otherwise the reagent would have exerted its normal effect.

The following process, devised by Fodor,[2] is said to be of sufficient delicacy to detect 1 part in 20,000. Fresh defibrinated blood is mixed with 10 volumes of water and introduced into a large jar containing the suspected air. After being allowed to stand for about an hour without shaking, it is transferred to a small flask provided with a rubber stopper carrying two glass tubes, one of which dips beneath the surface and connects at its outer end with a potash bulb containing palladium chloride solution. The other tube serves as an outlet, and is connected with a series of three potash bulbs containing respectively lead acetate solution, dilute sulphuric acid, and palladium chloride so diluted that it has a bright-yellow color. The terminal bulb is connected with an aspirator, which, when set in action, draws a current of air through the five different pieces. The flask containing the blood is heated on a water-bath for fifteen to thirty minutes with occasional shaking, and meanwhile a slow current of air is drawn through the apparatus. When the blood begins to change color, the carboxyhæmoglobin decomposes and yields its CO, which reduces the palladium contained in the terminal bulb. The chloride of palladium in the first bulb is used for removing any traces of the gas and of other reducing agents in the aspirated air. At the close of the operation, if the blood contained CO, the palladium chloride in the terminal bulb shows

[1] Loco citato, p. 8.
[2] Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, Vol. 12.

a precipitate of reduced palladium and the liquid has a somewhat darker tint. The lead acetate and dilute sulphuric acid serve to remove any traces of sulphuretted hydrogen and ammonia, both of which substances will cause precipitation of the palladium.

Other qualitative tests of greater or less delicacy include the following:

1. Mix 5 cc. of exposed blood solution and 15 cc. of a 1 per cent. solution of tannic acid. The resulting precipitate, which settles very slowly, has a brownish-red color, if CO was present in the air; otherwise it is grayish-brown.

2. Mix 10 cc. of the blood solution with 5 cc. of a 20 per cent. solution of potassium ferrocyanide and 1 cc. of acetic acid (1 part of glacial acetic acid to 2 of water). A reddish-brown precipitate is indicative of the presence of the gas, and one of grayish-brown shows its absence.

3. Bring together on a porcelain plate 1 drop each of exposed defibrinated blood and sodium hydrate solution of a specific gravity of 1.300. With CO blood, the color is bright red, while with normal blood it is brownish or blackish.

4. In place of the above reagent, use a mixture of 1 part of the same with 3 of calcium chloride solution. CO blood gives a carmine, and normal blood a light-brown or brownish-red, color.

5. Draw air through a tube containing a solution of cuprous chloride, which, in the presence of CO, deposits a characteristic precipitate, which, according Berthelot, is $Cu_2Cl_2CO.2H_2O$.

Quantitative Determination.—Nicloux[1] has devised a colorimetric method for which he claims great accuracy. It is based upon the fact that, by the action of carbon monoxide on iodic acid, definite amounts of iodine are set free. He combines this with an alkali, acidulates and shakes out with chlorform or carbon disulphide, and then compares the color with solutions containing known amounts of iodine. From the amount of iodine, the amount of CO which caused its liberation may be reckoned.

Gautier[2] allows the liberated iodine to act upon copper foil, and determines the amount of CO from the increase in weight. He also determines the CO_2 produced by the action of iodine pentoxide on CO; the result indicates volume for volume. Potain and Drouin[3] recommend a colorimetric method by means of dilute palladium chloride solution.

Determination of Ozone.—The allotropic form of oxygen acts upon potassium iodide in the presence of moisture and converts it to hydrate, with liberation of iodine, according to the following formula:

$$2KI + H_2O + O_3 = 2KOH + O_2 + I_2.$$

This reaction is the basis of most of the processes which have been proposed for qualitative and quantitative determination, none of which may be regarded as of value, since there are many sources of error to

[1] Comptes rendus, CXXVI., p. 746.
[2] Ibidem, CXXVI,. pp. 871, 931, 973.
[3] Ibidem, p. 938.

be taken into account, sources impossible to eliminate and of importance impossible to compute.

The presence of ozone in the air is supposed to be demonstrated when, on exposure of paper saturated with starch paste containing potassium iodide, a blue color gradually develops, owing to the action of the liberated iodine on the starch. Quantitative determinations are made by comparing the tint with a standard scale, the depth of color being dependent upon the amount of iodine liberated, and this upon the amount of ozone present. The papers are prepared in the following manner: From 2.5 to 10 grams of starch are taken, according to the recommendations followed, and, after trituration with a small amount of cold water, are boiled for about ten minutes in about 200 cc. of water, and filtered. One gram of potassium iodide in solution is next added gradually with constant stirring. Strips of stout filter-paper, wet with distilled water, are soaked in the starch preparation until they are thoroughly impregnated (about two to four hours), then removed with the aid of forceps, spread flat, and dried in the dark. When used, they are hung up out of the direct sunlight and exposed for a definite time, then removed, moistened with water, and compared with the scale. The objections to the process are that a number of other substances which may be in the air, such as certain volatile organic acids, chlorine, nitrous acid, and hydrogen peroxide, cause this same chemical reaction; that the blue color is destroyed by other substances, as sulphuretted hydrogen and sulphurous acid; and that light, moisture, heat, and wind exert very decided modifying influences. Thus, wind brings more air into contact, sunlight bleaches the color, moisture hastens the bluing, and heat dissipates the free iodine.

In order to differentiate between ozone and nitrous acid, it has been proposed to use neutral litmus (violet) paper instead of ordinary filter-paper in making the strips. The KOH formed in the reaction will change the violet to blue, while nitrous acid, chlorine, and organic acids will convert it to red, or bleach it, or leave it unchanged.

In spite of the fallacies mentioned, the weight of evidence thus far obtained in ozonimetry shows that the reaction with starch is most marked in pure air at the seashore and at great heights, and that but little reaction occurs indoors.

Determination of Dust.—Dust is determined quantitatively in two ways, and the results are expressed in terms of weight or of number. In order to ascertain the *weight* of the dust contained in a given volume of air, a chloride of calcium tube, containing perfectly dry absorbent cotton or glass wool, is weighed accurately, and then attached to a water suction-pump with an air-meter between. A large amount of air, say 500 liters, is then drawn through as quickly as possible. When a sufficient amount has passed, the tube is detached and placed either in a drying-oven or in a desiccator over sulphuric acid, and kept until it ceases to lose weight (moisture). The

net increase in weight represents the amount of dust in the volume of air aspirated.

To determine the number of dust particles in a given volume, the method of Aitkin is employed. The apparatus includes a shallow metallic box with glass top and bottom etched in squares. Into this box, containing air which has been freed from dust by filtration through cotton, and is kept saturated with moisture by means of wet filter-paper, a small measured amount of the air under examination is introduced. By causing the formation of a partial vacuum, each particle of dust becomes coated with condensed moisture and hence tends to fall upon the etched squares of the bottom. The number deposited is counted with the aid of a magnifying glass. The number of particles varies, according to Aitkin's observations, from 8,000 to 100,000 per cubic inch in the country, and from 1,000,000 to 50,000,000 in cities.

Bacteriological Examination.—The method which involves the least trouble and requires a minimum of apparatus, and which for all practical purposes gives greatest satisfaction, consists in exposing gelatin plates or Petri dishes for a definite period, and then covering them and letting the colonies develop. After the proper interval, the number of growths may be counted, and the individual species isolated and studied. This method is very useful for comparative work, the results being given as the number of colonies which develop after a given exposure.

For more accurate quantitative work, Petri[1] devised a process of sand filtration. A glass tube, 9 by 1.6 cm., serves to carry two small filters, which are arranged in the following manner: Two small tightly fitting diaphragms of fine wire gauze are inserted into the tube at a point midway between the ends. Into one side, a quantity of fine quartz sand is packed, and upon it, to keep it in place, another diaphragm is driven. Above this, the space is filled with a cotton plug. The tube is now reversed and a second filter of sand is made in the same way. After complete sterilization, the cotton plug in one end gives way to a rubber stopper with a single perforation, through which passes a glass tube connected with an aspirating pump. The other cotton plug is removed and the process of suction begun. When a sufficient amount has been drawn through, the two filters are removed, each by itself, and mixed with the nutrient gelatin from which plates are next to be made. The first filter should contain all of the organisms, the second serving as a control.

Ficker suggested an improvement in the construction of the filters, substituting for sand, which to a certain extent, masks the colonies, powdered glass, which has not this disadvantage. A still better material is fine sugar, the use of which was suggested first by Sedgwick. The advantage of this is that it is dissolved in the liquefied gelatin, and thus disappears from view, and, therefore, neither masks the colonies nor can be mistaken for them in counting.

[1] Zeitschrift für Hygiene, III., p. 1.

Sedgwick's method of collecting organisms and obtaining cultures is one which, on the whole, is preferable to any other that has been suggested. His apparatus, known as the aërobioscope, is a glass tube about 14 inches in length, shaped like a hydrometer and open at both ends. The narrow portion, which is rather less than half the length of the tube, has an internal diameter of 0.2 inch; the broader portion has an internal diameter of 1.8 inches, and at its free end is constricted for an inch to about half its size. Into the outer end of the narrow portion, a diaphragm consisting of a roll of fine wire gauze is inserted to act as a plug for the sugar filter. The two open ends are stopped with cotton, and the apparatus is then sterilized. The plug at the larger end is next removed and the sugar, sufficient in amount to fill the small tube above its contained diaphragm, is introduced. The plug is replaced, and then the whole is sterilized at 120° C. for several hours. In use, the apparatus is held in a vertical position with the narrow portion down, the plugs are removed, and a measured volume of air is drawn through by means of an aspirating apparatus connected by a rubber tube to the lower end. When the desired amount of air has been aspirated, the sugar with the bacteria which it has arrested is brought, by proper manipulation, into the broad part, into which, by means of a bent funnel, a sufficient amount of liquefied nutrient gelatin is introduced. The plug is replaced, and the tube is then rolled and chilled on ice, and set aside for the development of colonies. After the proper interval, the count is made in the usual manner.

The methods above given have generally superseded that of Hesse, who was a pioneer in this branch of investigation. His apparatus consists of a glass tube, 28 inches long and about $1\frac{1}{2}$ wide, supported in a horizontal position upon a wooden tripod. One end is covered with two rubber caps, the inner of which has a single perforation; the other end is closed with a rubber stopper with an outlet tube of glass plugged at each end with cotton and connected with a pair of aspirating flasks of a liter capacity. The tube is sterilized and charged with 50 cc. of gelatin, which is allowed to solidify before use. In conducting the operation, the outer cap is removed, thus exposing the inner perforated one, and a current of air is drawn slowly through by the action of the aspirating flask, which, filled with water, empties itself into the other. By reversing the flasks, any number of liters of air may be drawn through. In its passage, the air deposits its bacteria on the gelatin. The process has many disadvantages, and can make no great claim to accuracy.

CHAPTER III.

THE SOIL.

NOTWITHSTANDING the constant and necessarily intimate relation of all life to the soil upon which we build our habitations, from which we derive in such great part our supply of drinking-water, into which we cast vast quantities of organic filth, and to which we consign our dead, the subject of the sanitary importance of the soil has not until within comparatively recent years received the attention which it merits. That the soil exerts important influences on the public health, was recognized long before the time of Hippocrates, and extensive researches on the subject figure among the earliest investigations of the modern hygienist, but by far the greatest part of the attention paid to the study of the soil has been due to considerations of public wealth rather than of public health. With the gradual development, however, of a more accurate knowledge of the causes of disease, has come an increasing interest in the relations of the soil to those causes, and what has hitherto been a rather neglected field of exploration now bids fair to be well and thoroughly tilled.

That portion of the earth's crust in which we as hygienists are interested includes the superficial layer, known as tilth or arable soil, which is the result of the disintegration of rocks and decay of animal and vegetable life, and the subsoil, which lies directly beneath. The former varies from a few inches to several feet in depth; the latter extends few or many feet downward to the hardpan or other impermeable stratum.

Soil is a mixture of sand, clay, and other mineral substances, with humus, or organic matter, and living organisms; and it is classified according as one or another of its constituents predominates. The usual classification of soils includes sands, clays, loams, marls, humus, and peats.

Sandy soils consist almost wholly, or at least more than four-fifths, of pure sand of any kind.

Clays are stiff soils consisting chiefly of silicate of aluminum and other very finely divided mineral matters. Clay exists in particles of the smallest possible size, is very cohesive, possesses a high degree of plasticity, and plays a very important part in determining the fertility of soils, their texture, and their capacity for holding water. Its plasticity is due to the presence of a small proportion of hydrated silicate, and is modified very greatly by the addition of less than a hundredth part of caustic lime. It is exceedingly impermeable to water, and when wet dries with great slowness.

Loams are mixtures of sand, clay, and humus; hence their properties partake of the characteristics of these substances according to the extent to which each is present. When sand predominates, they are designated as *light;* and when clay prevails, they are known as *heavy.* These terms, however, have no reference to weight, but to the ease or difficulty with which they are worked in the processes of agriculture; and, indeed, those soils which are the lightest in this sense are the heaviest in actual weight. Since loams consist of varying proportions of the chief constituents, it is obvious that the word loam may have but little significance without some qualifying term, and they are, therefore, divided into five classes, as follows:

1. Heavy clay loam, containing	10–25	per cent.	of sand.
2. Clay loam, containing	25–40	"	"
3. Loam, containing	40–60	"	"
4. Sandy loam, containing	60–75	"	"
5. Light sandy loam, containing	75–90	"	"

Mixtures containing less than 10 or more than 90 per cent. of sand are classed, respectively, as clay or sand.

Marls are mixtures of clay, sand, and amorphous calcium carbonate in various proportions, and contain, often, potash or phosphates from the fauna and flora of the sea. From their content of carbonate of calcium they are known often as lime soils, and according as one or another constituent predominates they are designated as clay marl, sand marl, and shell marl. All contain varying amounts of humus.

Humus is a term used to designate the entire product of vegetable decomposition in the various intermediate stages of the process. It is the essential element of vegetable mould, and is necessarily of most complex composition—so complex, indeed, that it cannot definitely be determined. It is composed of a great number of closely related definite chemical compounds, chief among which are ulmin and ulmic acid, which are supposed to characterize brown humus; humin, and humic acid, which dominate dark, or black humus; and crenic and apocrenic acids. Its principal characteristic is its high percentage of nitrogen, especially marked in some of our prairie soils and in the "black soil" found in the provinces of the Ural Mountains, which, according to Von Hensen,[1] contains as much as from 5 to 12 per cent. of organic matter. Its complete decay is most rapid in warm well-drained soils permeable to air, and in such soils the amount of humus present at any one time will be relatively small, while in soils which are damp, not well ventilated, and, for months at a time, frozen, its accumulation is favored. While its ultimate products of decay are of the greatest importance to vegetable growth, it does not follow that its complete absence renders a soil necessarily sterile, or even poor, provided the necessary nitrogen is supplied in the form of nitrates. But its presence is necessary to the growth and life processes of the soil bacteria, without whose assistance many plants would fail to thrive.

Peat, muck, and *humus soils* contain large amounts of humus, but differ

[1] Zeitschrift für wissenschaftliche Zoologie, XXVIII., p. 360.

according to the conditions under which they are formed. *Peat* and *muck* result from the incomplete decay of vegetable matter under water; the former term applies to that which is compact and fibrous; the latter is less compact, not fibrous, and, when dry, easily reduced to powder. They contain but a small amount of mineral matter. *Humus soils* are soils which contain large percentages of vegetable mould with ordinary soil constituents.

The expression *rocky soil* applies to any kind of soil containing masses of rock.

Gravelly soils are those which contain notable amounts of gravel, which consists of small fragments of rock more or less worn by the action of water, and larger and coarser than sand.

Alkaline or *salt soils* are soils which contain considerable amounts of soluble salts, especially carbonate and sulphate of sodium and salts of calcium.

Constituents of the Soil.—The chief constituent of the soil is silica, which, it is estimated, forms about two-thirds of the entire earth's crust. Next in abundance is aluminum, chiefly in the form of clay (silicate of aluminum). Lime and magnesia are large constituents, existing chiefly as carbonates in the form of limestone. Both are indispensable to the growth of plants, and lime exerts a marked influence on the physical condition of the soil and upon the processes of nitrification. Although its principal combination is carbonate, it exists also largely as phosphate and sulphate.

Iron is universally present, and is of very great importance to vegetation, although but a small amount is needed. The red and yellow colors of soils are due to the presence of iron compounds. Manganese stands second to iron in abundance among the heavy metals, but is of much less importance. It is a constituent of many plants, notably of tea. Chlorine is not a large constituent; it occurs chiefly in combination with sodium, potassium, and magnesium. Its total amount in ordinary unpolluted soil seldom exceeds $\frac{1}{10000}$ part of the whole. Sulphur occurs as sulphides and sulphates, the latter usually in combination with calcium. It is very necessary to vegetable growth, as it is an essential element of vegetable albumin. Phosphorus in the form of phosphates of lime, magnesia, iron, and alumina, is another essential element, widely distributed in small amounts. Sodium and potassium are present, chiefly in the form of insoluble silicates and partly as chlorides. Their total in combination seldom exceeds 4 per cent.

Nitrogen exists in soils in three distinct forms: proteids, ammonia and its salts, and nitric acid and nitrates. In average soils, the total nitrogen is not large in amount—considerably less than 1 per cent.—but in some exceptionally rich humus soils 4, 5, and even 6 per cent. are found. In the organic combinations (proteids) it is not available as plant food, consequently these must be broken up into simpler forms in order to be of direct use. In their decomposition, the second form, ammonia, is produced, but not all the ammonia of the soil is from this source, for some is brought into it from the air by rain. And in the

second form, also, it appears to be not available as plant food, but even, according to Bouchardat and Cloëz,[1] seems to act as an energetic poison when absorbed by plant roots from solutions of 0.1 to 0.01 per cent. strength. So it is probable that complete oxidation to the third form is necessary for the absorption of any form of nitrogen. As soon as the ammonia is oxidized in its turn to nitric acid, this latter combines with sodium, potassium, or calcium, and the resulting nitrates are then ready for absorption.

All of these changes from the complex proteid to the simple nitrate are carried along by different groups of micro-organisms, but no great accumulation of the end products occurs, because, while vegetation is flourishing, they are removed as fast as formed, and when it has ceased, they are washed down into the subsoil by the rain and melting snow.

The amount of organic matter in soils varies widely according to circumstances, but the amount necessary for vegetation is quite small, although certain crops, as tobacco and wheat, require much more than others, as oats and rye. The soils richest in organic matter are the peats and mucks; next come the very rich humus soils, which may yield more than a fourth of their weight. From 10 to 15 per cent. denotes unusual richness, and about 6 per cent. may be regarded as a fair amount for a productive soil.

Physical Properties of Soils.—Pore-volume.—In all soils, no matter how closely the individual particles are packed, there must exist a greater or less amount of interstitial space, which may be filled with water or air, or both together. The sum total of these interstitial spaces is known as the *porosity* or *pore-volume*, and is expressed in percentage of the volume of the soil. Its amount depends not upon the size of the soil particles, but upon their uniformity or lack of uniformity of size, and upon their arrangement. If we have, for instance, a

FIG. 15.

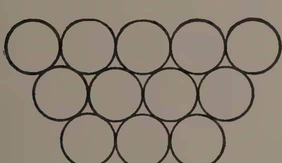
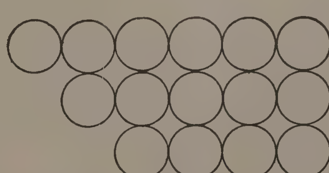


FIG. 16.



very coarse soil, consisting of particles of uniform size as large as peas, and another of uniform particles the size of small shot, we shall find, on determining their pore-volume, that it is practically the same in each case, and is probably not far from a third of the whole. Packed in the most solid manner possible, which is that in which each sphere rests on three beneath it (arranged like the familiar pyramid of marbles), helps support three in the layer above it, and comes in contact with others at six equidistant points along its equator, as in Fig. 15, the volume of interstitial space will equal 25.95 per cent. of the whole. Packed as loosely as possible, so that each rests upon but one, sup-

[1] Deutsche medicinische Wochenschrift, 1886.

ports another, and comes in contact with but four of its neighbors in the same layer as itself, as in Fig. 16, the volume of the interstices will be 47.64 per cent.[1] Thus a soil composed of spherical grains of uniform size would have, regardless of the coarseness of the grains, a pore-volume of not less than 25.95 per cent.

That the size of the individual grains makes no difference, may easily be demonstrated in a practical manner. If we take two cylindrical glass vessels of the same size, fill them to the same height with water, and then add to the one a measure of large shot and to the other an equal measure of much finer shot, and secure as solid packing as possible by gentle tapping, it will be found that the water in each cylinder has risen to practically the same height; that is, that the actual volume of each is about the same. There will be, perhaps, some slight difference one way or the other, owing to the impossibility of securing absolute uniformity of packing, and to the error due to the inequality of the spaces along the circumference of the cylinders. But in nature we do not deal with perfect spheres or with soils made up of particles all of the same size, but with soils composed of angular pieces of varying size. The greater the variation in size of the particles, the greater the possibility of variation from the limits of pore-volume as given above. With varying size, the small particles may fall into the spaces made by the larger ones, and the spaces between the new comers may be trespassed upon by still smaller grains, and so on until the interstitial space has been reduced to a minimum.

To illustrate this diminution in a practical way, fill a large beaker with marbles, then pour into it, from a graduate, sufficient water to displace all of the air in the interstices, and note the amount of water required, which is the pore-volume of the mass. Next, pour out the water as completely as possible and run on to the surface of the marbles a quantity of coarse sand or shot, and shake the vessel gently in all directions so as to favor their descent into the spaces below. When all have penetrated that can, pour in water again until it appears at the surface, and note the amount required; this is smaller than before, on account of diminished air spaces. Now pour off the water a second time, add still finer shot, and repeat the operation as before. So long as new matter can be added, so long will the pore-volume show a diminution.

Irregularity of size and shape of the particles may also have an influence in the other direction, and cause the formation of large spaces and increased pore-volume.

All soils, even the most compact rocks, have a certain amount of pore-volume, and some apparently compact masses, such as sandstone, have as much as 30 per cent. In soils which are cemented into homogeneous masses, the pore-volume sinks to a minimum, but in ordinary soils it amounts to about 40 per cent.

Permeability of Soils.—The permeability of a soil to air depends not, as it might appear, upon the amount of its pore-volume, but upon

[1] Soyka, Der Boden, Leipzig, 1887.

the size of the individual spaces. In fact, a soil of high pore-volume may be almost impermeable to air in comparison with one of less pore-volume, as will be shown; and the pore-volume is of itself no measure whatever of permeability, which diminishes in an extraordinary degree with diminution in the size of the soil particles. The greater the number of the individual spaces, the greater the number of angles and the greater the friction of the entering air; and, conversely, the less the number, and consequently the larger the size of the spaces, the less the number of angles and the less the obstruction. A series of experiments conducted very carefully by Renk[1] with different kinds of soil in cylinders of equal height, through which air was forced under the same degree of pressure, yielded the following interesting results:

Nature of soil.	Diameter of grains.	Pore-volume %.	Pressure in mm. of water.	Amount of air in liters per minute.	Ratio.
Fine sand	Less than ⅓ mm.	55.5	20	0.00133	1
Medium sand . . .	⅓ to 1 mm.	55.5	20	0.112	84
Coarse sand	1 to 2 mm.	37.9	20	1.280	961
Fine gravel	2 to 4 mm.	37.9	20	6.910	5,195
Medium gravel . . .	4 to 7 mm.	37.9	20	15.540	11,684

Thus it is seen that a fine sand with a pore-volume of 55.5 per cent. permitted the passage of but 1 volume of air, while a gravel of medium coarseness with much lower porosity permitted the passage of 11,684 times as much in the same unit of time. Renk showed, farther, that with soils of the finer textures, permeability to air is directly proportionate to pressure, but that this is not true of those of coarser grain.

Nature of soil.	Size of grain.	Height of column.	Units of pressure.	Ratio of volume of air passed.
Fine sand	Less than ⅓ mm.	0.50 m.	1	1
			1.5	1.5
Medium sand	⅓ to 1 mm.	0.50 m.	1	1
			2	2
			3	3
		2.00 m.	1	1
			2	2
			3.6	3.6
Coarse sand	1 to 2 mm.	0.50 m.	1	1
			2	1.91
			3	2.78
		2.00 m.	1	1
			2	2
			3	2.9
Fine gravel	2 to 4 mm.	0.50 m.	1	1
			2	1.67
			4	2.30
		2.00 m.	1	1
			2	1.77
			3	2.42
Medium gravel	4 to 7 mm.	2.00 m.	1	1
			2	1.65
			3	2.19

[1] Zeitschrift für Biologie, XV., p. 205.

The absence of any connection between pore-volume and permeability has been shown also by von Welitschkowsky,[1] from whose results the following table has been constructed:

Nature of soil.	Pore-volume %.	Pressure in mm. of water.	Amount of air in liters per minute.	Ratio.
Fine sand	41.87	50	0.0058	1
Medium sand	40.64	50	0.8990	155
Coarse sand	37.38	50	7.399	1,276
Fine gravel	35.47	50	33.651[2]	5,802

Since permeability diminishes with fineness of texture, it follows that clay and similar soils possess this property in the smallest degree, and that when these are mixed with sandy soils they must necessarily lessen it to a very marked extent. But clays and loams may occur in very open crumbly form, that is, in loose fragments of varying size, each consisting of myriads of small particles held together by the aid of moisture; and such soils show a high permeability, due to their large interstitial spaces.

The degree of permeability to air is influenced very greatly by the amount of contained moisture, the maximum influence being exerted by decided wetness. This is due to the fact that the greater the amount of water present in the interstices, the greater the diminution in the space available for the passage of air and the greater the obstruction to its movement. Thus the complete occlusion of the interstices by water is equivalent to absolute impermeability, except when the pressure of air is sufficient to displace the water and move it along.

In the case of soils that are only partially wet, the diminution in permeability varies according as the moisture enters from above by rain or from below by capillary attraction from the water in the subsoil. This is owing to the fact that when the soil is wetted from above by rain, the superficial interstices are occluded more or less completely, and the air in those below is restrained in its movement; while when the moisture is derived by capillary attraction, the air is displaced upward, and the superficial interstices are more or less completely open. The action of downward and upward moistening has been investigated by Renk,[3] whose results, in part, are given in the following table:

[1] Beitrag zur Kenntniss der Permeabilität des Bodens für Luft: Archiv für Hygiene, II., p. 483.

[2] The height of the column of material in this experiment was three-fourths of a meter, instead of a half, as in the case of the three others. With an equal height the result would have been much larger.

[3] Loco citato.

Nature of soil.	Pore-volume %.	Moisture.	Pressure.	Ratio of air passed.
Medium gravel	37.9	absent	20	15.54
		from above	20	14.63
		from below	20	13.70
Fine gravel	37.9	absent	40	14.04
		from above	40	13.16
		from below	40	12.55
Coarse sand	37.9	absent	40	2.33
		from above	40	1.91
		from below	40	1.71
Medium sand	41.5	absent	150	0.57
		from above	150	0.11
		from below	150	0.00
	55.5	absent	150	0.04
		from above	150	0.03
		from below	150	0.00
Fine sand	55.5	absent	150	0.01
		from above	150	0.00
		from below	150	0.00

Permeability is lessened also by freezing temperatures, by reason of the fact that the contained moisture expands about one-eleventh of its volume as it freezes, and so occupies that much more space in the interstices. Moreover, when frozen, the moisture is in a fixed rather than a movable condition, and causes the production of a compact mass more or less resembling stone. The finer the grain, the more solid the product, and the greater the diminution of permeability. Renk[1] determined the diminution in the permeability of soils of different grain size due to freezing, as follows:

Nature of soil.	Source of moisture.	Permeability.		Diminution.
		Moist.	Frozen.	
Medium gravel	from above	14.63	13.87	5.2%
" "	" below	13.70	12.20	10.9
Fine gravel	" above	13.16	12.54	5.4
" "	" below	12.55	10.18	19.0
Coarse sand	" above	1.91	1.64	14.1
" "	" below	1.71	1.27	25.7
Medium sand	" above	0.11	0.07	36.4
" "	" below	0.00	0.00	——
" "	" above	0.23	0.00	100.
" "	" below	0.00	0.00	——

The degree of permeability of soil to water, like that of permeability to air, is governed by the texture rather than by pore-volume, as is shown by the following results obtained by von Welitschkowsky,[2] who determined the rates at which water would pass through columns of soil of differing fineness packed in cylinders of equal diameter. Each

[1] Beitrag zur Kenntniss der Permeabilität des Bodens für Luft: Archiv für Hygiene, II., p. 483.

[2] Experimentelle Untersuchung über die Permeabilität des Bodens für Wasser, Archiv für Hygiene, II., p. 499.

specimen was first completely saturated and then kept so during each experiment, the water supplied being kept at constant level.

Height of column of soil.	25 cm.		50 cm.	
Height of water column above soil surface.	20 cm.	50 cm.	20 cm.	50 cm.
Nature of soil and size of grain.	Amount of water discharged in liters per min.			
Fine sand, less than $\frac{1}{3}$ mm.	0.00024	0.00059	0.00014	0.00028
Medium sand, $\frac{1}{3}$ to 1 mm.	0.175	0.435	0.123	0.237
Coarse sand, 1 to 2 mm.	1.767	4.014	1.351	2.422
Fine gravel, 2 to 4 mm.	8.570	16.190	7.465	11.705
Medium gravel, 4 to 7 mm.	14.909	——	12.872	——

Comparing these results with those obtained by the same investigator in his experiments on permeability to air, it will be noticed that the total pore-volume has here even less significance.

Nature of soil.	Height.	Pressure.	Pore-volume %.	Ratio of permeability.	
				To air.	To water.
Fine sand	50 cm.	50 cm.	41.87	1	1
Medium sand	50 cm.	50 cm.	40.64	155	846
Coarse sand	50 cm.	50 cm.	37.38	1,276	8,650

Capacity for Water, and Water-retaining Capacity.

If to a volume of any soil packed into a cylinder of glass or metal we add water in such a way that all of the air in the interstices is displaced, the soil is then saturated and the amount of the contained water represents the total "water capacity," which, it is seen, equals the pore-volume. The "water-retaining capacity," is quite another thing, and depends upon the structure and composition of the soil, and, in a minor degree, upon other considerations. If for the impervious bottom we substitute one of wire gauze or coarse cloth, the contained water will begin to drain away, owing to the force of gravity, and the flow will by degrees become less and less, and finally cease. Then the interstices, which originally were filled with air alone and next with water, are filled in part with the one and in part with the other.

By comparing the original weight of the volume of soil with its weight in its now wet condition, its power to retain water is easily determined. This power is the result of two forces acting in opposition to the force of gravity; namely, surface attraction of solids for liquids, and capillary attraction. The water which is simply adherent to the surfaces of the soil grains is known as hygroscopic water, while that which is held in the capillary spaces is called capillary water; and it is the latter which, in any but the coarsest soils, constitutes by far the larger part of the retained moisture.

Not all of the interstices of a soil form capillary spaces, but only those of which the boundary walls are separated only by intervals

which come within the limits of capillary magnitude. Thus, a coarse soil may contain comparatively few such spaces, while one of a fine texture may have its particles so closely approximated that all of its interstitial spaces are capillary. It follows, therefore, that compact soils possess greater retaining power than those with large interstices which permit rapid percolation, and that when the texture is so fine that all the spaces are capillary, the maximum retaining power is attained.

The influence of soil texture on capacity for holding water may be seen in the following table of some of the results obtained by Hofmann:[1]

Diameter of grain in mm.	Pore-volume per 1,000 cc.	Amount of contained water in cc.	Amount of contained air in cc.	Per cent. of pore-volume filled with water.
5	434	55	379	12.7
3	418	77	341	18.4
2	410	98	312	23.9
1	400	150	250	37.5
0.5	413	270	143	65.4
less than 0.5	413	347	66	84.0

The water-retaining capacity of soils is determined very largely also by the amounts of organic matter present; a soil rich in organic matter will, other conditions being the same, show more water than another of less richness. The extreme influence is observed in the case of humus, which can hold ten times its weight of water. In view of this influence of organic matter, it is very clear that one way to help keep a soil dry is to avoid discharging filth into it, and thus keep it clean.

For the purpose of illustrating the influence of very fine soil particles (clay) and of organic matter (humus), the following results of an investigation by Wolff[2] may be quoted. He packed soils of varying clay and humus content into a metallic vessel with a permeable bottom, saturated them completely with water, then superimposed a column of water of equal cross-section and 8 cm. high, and observed the time required for the added water to be delivered below:

Nature of soil.	Percentage of clay.		Percentage of humus.	Time required.	
	Per cent.	Ratio.		Hours.	Ratio.
Very fine sandy loam	15.74	1.	0.88	20.3	1.
Very fine sandy loam	15.96	1.+	1.40	25.8	1.27
Black, rich, chalky loam . . .	18.17	1.15	6.87	31.0	1.52
Very fine sandy loam	25.93	1.64	0.92	75.8	3.73
Very clayey soil	42.56	2.70	0.66	133.0	6.55
Soil with considerable clay . .	29.76	1.89	2.19	188.0	9.26

It will be observed that the soil which permitted the passage of the water in the shortest time was poorest in clay and almost so in humus,

[1] Archiv für Hygiene, I., p. 273.
[2] Anleitung zur chemischen Untersuchung landwirthschaftlich wichtiger Stoffe, 1875.

and that the one which required the longest time combined a considerable amount of clay, not the highest, with a high percentage of humus, also not the highest. The highest percentage of clay was associated with the lowest amount of humus, and the highest of humus with a low content of clay; but these two soils (Nos. 5 and 3) were both less impermeable than that (No. 6) which contained less clay than the one and less humus than the other. It is to be noted, however, in the case of the soil with the highest proportion of clay and lowest of humus, that it contained 12.8 per cent. of chalk as against 2.28 per cent. in the most impermeable, and that this substance, as has been mentioned, has a very great influence in diminishing the degree of plasticity of clays.

Soil Temperature.

The sources of heat in the soil are three in number; namely, the sun's rays, chemical changes, and the original heat of the earth's interior. The principal source is the sun. The heat derived from chemical changes is not great, and, indeed, is not even worthy of consideration, except in soils very rich in organic matter; and here the changes occur only in the presence of comparatively high temperature due to the action of the sun. The third source is constant and of much importance.

The soil temperature is influenced by a number of conditions, including exposure, atmospheric temperature, color, compactness, composition, and moisture. Naturally, the surfaces exposed to the greatest amount of sunshine get more heat than others. The nearer the angle of incidence of the sun's rays approaches a right angle, that is, the more perpendicularly the rays strike, the greater the amount of heat received.

The rapidity with which soils are affected in either direction by changes in atmospheric temperature varies widely, but with any soil it is only in the very uppermost layers, the very surface in fact, that any immediate corresponding rise or fall is observed. Great sudden changes affect the soil below the surface very slowly, and in the deeper layers the maximum and minimum temperatures occur much later than in the atmosphere above. The annual variation diminishes as the distance from the surface increases; at fifteen feet the amplitude is, as a rule, less than 10 degrees F., and between fifty and eighty feet the temperature is constant the year round.

The color of a soil exerts an important influence in the determination of its temperature. As is well known, a black surface exposed to the sun absorbs the heat rays more than a white one. A common illustration of this fact is the greater rapidity with which snow melts when its surface is dotted over with dirt and soot than when it is clean and white, owing to the absorption of heat by the dark particles and its communication by conduction to the snow beneath and about. In the same way, soot and cinders work their way downward into the ice on a pond. Another illustration is the greater feeling of

warmth conferred by black clothes than by white in the bright sunshine.

So, other conditions being the same, a dark soil is warmer than a light one, which reflects the heat rays instead of absorbing them. Observation has shown a difference of more than 25 degrees F. in the temperature of black and white sands exposed side by side to the direct rays of the sun, but the white sand by reason of reflecting the heat rays will appear to be much hotter than it really is.

The influence of compactness on soil temperature varies with the season. According to King,[1] the general tendency of rolling the land is to make it warmer during bright, sunny weather, but in cloudy or cold weather it tends to promote cooling. He has observed that, at the depth of 1.5 inches below the surface, a rolled field may have a temperature 10 degrees F. higher than a similar soil not rolled, and at double the distance he has noted a difference of 6.5 degrees. This is due chiefly to the fact that a compact soil is a better conductor of heat than one containing large interstices filled with air.

The character of the mineral and organic constituents of the soil and the amount of its content of water exert the very greatest influence upon its temperature. Rocks, sands, and mineral substances in general are better heat conductors than water, organic matter, and air, and they differ also one from another in conductivity. Organic matter is a particularly poor conductor of heat, and hence the greater the amount of humus a soil contains, the slower its response to the action of the sun.

The great influence of moisture on soil temperature is due to the high specific heat of water, and to the loss of heat which accompanies the process of evaporation. The specific heat of ordinary dry soils varies from a fifth to a fourth of that of water, although in exceptional cases it may amount to nearly a half; and the wetter the soil is, the higher will be the specific heat of the mass, that is, the greater the number of heat units necessary to warm a given weight 1 degree. Thus it happens that a light-colored dry soil may, in spite of the great influence of color, attain a much greater degree of warmth than a dark one which is damp. The different soil constituents have different specific heats, ranging from about 0.16 for certain sands and clays, to about 0.44 for dry humus, that of water being unity. Thus, to raise the temperature of 100 pounds of water 1 degree will require 100 units of heat, while to perform the same office for equal weights of dry sand, weathered porphyry, weathered granite, and humus, will require respectively 16, 20, 30, and 44 units. Therefore, the same amount of heat necessary to raise a given weight of water 1 degree will raise the equivalent weights of these substances respectively 6.67, 5.00, 3.33, and 2.27 degrees.

But although the high specific heat of water is of importance in determining soil temperatures, the chief influence of moisture in this direction is due to the great loss of heat which accompanies the process

[1] The Soil, New York, 1898.

of evaporation, for the change from the liquid to the gaseous form is accomplished only at the expense of heat. The greater the amount of water evaporated from a given soil, therefore, the greater the expenditure of heat and the greater the lowering of the soil temperature. Conversely, the drier the soil, the less the evaporation, and the greater its warmth. Water does not, however, always tend to produce lowering of the temperature, for, in point of fact, it may and often does have the opposite effect. In the spring, for instance, when the frost is not yet out of the ground and when the interstices are filled with cold water derived from the melting ice and snow, the warmer rain hastens the removal of frost, and, as it sinks into the soil, displaces downward the colder water and consequently raises the temperature.

Changes in the Character of Soils Due to Chemical and Biological Agencies.

Chemical action is constantly at work in the soil, not alone on the organic constituents, but upon the mineral matters as well. The changes which occur in the latter are of importance to the hygienist almost solely in so far as they affect the quality of the drinking-water. Complicated processes involving the decomposition of organic matters give rise to quantities of carbon dioxide which, being taken into solution by the water in the interstices, assists in the production of still more complicated processes which engage the mineral constituents.

The changes which, from a public health point of view, are of the greatest interest are those which are in progress in the process known as the "self-purification" of soils, in which the complex organic matters are broken up and reduced to simple chemical substances through the intervention of bacterial life. In the end, the carbon is oxidized to CO_2, and the nitrogen either is set free, or is combined with hydrogen in the form of ammonia, or is oxidized to nitric acid and nitrates.

The process requires the presence of atmospheric air and of moisture not in excess, and is favored by temperatures between 53° and 131° F., the most favorable being 98°. It proceeds most vigorously and perfectly nearest the surface, and virtually ceases at a depth of more than three feet, little or no action occurring in the subsoil beyond that depth. If too much organic filth and its attendant moisture are present, the soil becomes boggy and the changes cannot proceed.

An influence of very great importance in its effects on the physical and chemical characteristics of soils is that exerted by earth worms, which live chiefly on half-decayed leaves, which they drag into their burrows to be used as food and as linings and plugs for the burrows as well. According to Charles Darwin,[1] their castings contain 0.018 per cent. of ammonia, and the humus acids, which have been proved to play a very important part in the disintegration of various kinds of rocks, appear to be generated within their bodies. They swallow earth both in the process of excavating their burrows and for the

[1] The Formation of Vegetable Mould through the Action of Worms.

nutriment which it may contain, and exert an important mechanical action on the soil grains, reducing their size by attrition within their gizzards. After filling themselves with earth, they soon come to the surface for the purpose of emptying themselves.

"In many parts of England a weight of more than 10 tons of dry earth annually passes through the bodies of worms, and is brought to the surface on each acre of land, so that the whole superficial bed of vegetable mould passes through their bodies in the course of every few years." From various data, Darwin calculated that the castings, spread out uniformly, would form, in the course of ten years, a layer varying from 0.83, in the case of a very poor soil, to 2.2 inches in ordinarily rich soils. Their mechanical action and that of ants, moles, and other burrowing animals have much to do with keeping soils open and friable.

Soil-air.

The air in the interstices of the soil differs from that of the atmosphere mainly in its richness in carbon dioxide, which arises from the decomposition of organic matters. It is also poorer in oxygen, but by no means always in a corresponding degree, and it is usually quite humid by reason of the presence of soil moisture.

The amount of carbon dioxide varies very widely in different soils and at different depths of the same soil, and it fluctuates very considerably also under differing conditions at any given point in the same soil. Other conditions being the same, the amount is most marked in soils rich in organic matter undergoing decomposition-changes. In soils poor in this respect, the amount may be no greater than in the atmosphere. Pettenkofer, for instance, found in the air of desert sand, which was devoid of organic matter, the same amount as was present in the air immediately above it.

In ordinary soils, the amount increases with the distance from the surface, as has been shown by Fodor,[1] who made a great number of analyses of air at different depths at a number of places, the observations extending over several years. The average amounts found at depths of 1, 2, 3, and 4 meters, expressed in parts per 1,000, were as follows:

Depth in meters.	1	2	3	4
Station 1	4.8	6.6	. . .	28.7
Station 2	13.7	14.3	20.1	. . .
Station 3	18.1	28.4	. . .	36.5

The influence of season also was shown by him to be very considerable, the highest amounts occurring during the hot months, and the lowest in winter. The averages by months are presented in the following table:

[1] Boden und Wasser, Braunschweig, 1882.

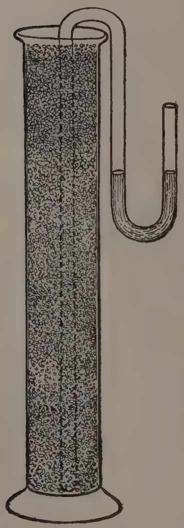
Month.	Depth in meters.		
	1	2	4
January	6.5	12.6	25.0
February	6.8	12.2	24.8
March	7.0	11.8	24.7
April	9.9	14.9	25.2
May	11.5	16.1	27.2
June	14.5	21.5	29.2
July	15.8	22.8	35.9
August	12.8	20.7	32.6
September	10.9	19.3	31.4
October	9.8	15.0	29.4
November	8.4	13.8	26.5
December	8.1	12.6	25.8

These results are only such as might be expected when we consider that decomposition of organic matters proceeds most vigorously within certain limits of high temperature.

Fluctuations in the amount present at any given point are due to a number of conditions which include rainfall, the action of the wind, the rise and fall of the subsoil-water, and differences in atmospheric pressure and temperature.

Rainfall, by filling the superficial interstices of the soil with water, interferes with the natural process of soil ventilation and causes an immediate accumulation of carbon dioxide, which, however, is shortly followed by a diminution due to absorption of the gas by the water, which thus acquires an increase in its power of attacking and dissolving the mineral constituents of the soil. Inasmuch as the bulk of the absorbed rainfall is held by the upper strata of the soil, its influence is more marked there than at greater depths. As it sinks downward, however, in very wet weather, it drives the air before it, and causes its escape at points where its egress is not obstructed.

Fig. 17.



Apparatus to show action of wind on soil air.

The action of wind is exerted in two ways: by perflation and by aspiration. By blowing strongly across the surface of the soil, it aspirates the air in the upper layers and causes an upward movement in the air below, or it may suck it out at one moment and take its place the next. Again, it may blow with such force against the surface as to drive the contained air downward before it, so that the interstices become filled with ordinary atmospheric air. The action is more marked in soils of ordinary coarseness of texture than in very open soils with large interstices, which permit freer movement in the upper strata. This may readily be demonstrated by means of a simple experiment with the apparatus shown in Fig. 17. Here we have a glass cylinder, inside which is a glass tube extending from the bottom

and bent over at the top so as to form a U, into which an amount of water sufficient to form a seal may be introduced. If now we fill the intervening space up to the top with sand, and then direct against the surface of the latter a current of air by means of a bellows or by blowing sharply through a tube of glass or other material, the whole volume of air in the interstices is set in motion, which is communicated to the air within the enclosed tube, so that the water in the U-shaped depression is caused to oscillate. If the water completely fills the short leg of the U, it may be forced over and caused to drip. If, however, instead of employing sand, we fill the cylinder with coarse gravel, the oscillation of the water will be either less noticeable or entirely absent, the air which enters at one point on the surface communicating its motion only to that immediately adjacent in the upper part.

The rise and fall of the water in the subsoil assist in the production of variations in the amount of carbon dioxide; on the one hand, by its rise, forcing the rich soil air upward and outward, and, on the other hand, by its fall, drawing the soil-air downward and causing its place in the upper strata to be filled with atmospheric air with low content of the gas.

Differences in temperature and barometric pressure have also been mentioned as exerting influence on the motion of the ground air. In spring and summer, the ground air is colder and denser; and in autumn and winter, it is warmer and lighter than the air above. Hence in the former, it tends to remain stationary or to sink; while in the latter, it rises and mingles with the atmosphere, which, under proper conditions, replaces it. Again, these changes may occur in both directions within the same space in twenty-four hours. For instance, at evening and at night the atmospheric air, being colder, enters the soil; while by day, being warmer, its direction is reversed, and air is drawn up from below.

Movement due to temperature differences is almost constant, since it is only rarely that the temperatures of the air and soil are in agreement. The influence of barometric pressure-changes is not very great; with fall in pressure, the tendency is toward upward movement, and with rise, toward downward movement; but Fodor found from the study of a large number of observations that the actual observable changes were insignificant.

With the various influences at work causing movement of the soil-air in all directions, it is plain that the soil, especially if highly permeable, is endowed with a sort of respiratory function which keeps it more or less well ventilated.

Formerly, it was believed by Pettenkofer and others of the "Munich School" that the amount of carbon dioxide in soil-air might serve as an index of the amount of impurity and of the rate at which the latter is decomposing, and that comparison of the amounts obtainable from different soils would serve to indicate their relative cleanliness. But such is not the case with soils equally permeable, owing to the influence exerted on soil ventilation by so many varying and conflicting causes.

Indeed, it has been proved by Fodor that a permeable soil extensively contaminated by organic filth may yield less of this index of impurity than one far cleaner, but less susceptible to ventilating influences.

Soil-water.

The moisture contained in the soil may be designated in three different ways, according to its position and the forces by which it is held in place; namely, hygroscopic, capillary, and gravitation.

Hygroscopic water is that which adheres to the surfaces of the soil particles in the presence of air. A certain amount of moisture is condensed upon the surface of most solid substances exposed to ordinary dampness, and it adheres with great tenacity. The amount of water so obtained differs, other conditions being the same, according to the nature of the soil, some soil constituents surpassing others in their power to attract it. Thus, soils rich in organic matter (humus) have a greater degree of hygroscopicity than others in which this constituent is present to a lesser extent. In some soils, the amount of hygroscopic water is very marked by reason of the large amount of organic matter, and because also of the large surface area presented by the soil particles. Some idea of the tenacity with which this moisture is retained may be derived from the fact that air-dried soils which appear to be quite dry—the dust of country roads, for instance—may yield as much as a tenth of their weight of water on complete drying by ordinary laboratory methods. Both the moisture absorbed from the air and the water held on the soil grains by surface attraction after a condition of decided wetness has been changed by the draining away of the rest, may be termed hygroscopic.

The capillary moisture is that which is held within those spaces which have been spoken of as capillary in their nature. Under ordinary conditions, these are intermingled with spaces which may not be so designated and which contain air, and so the capillary moisture does not ordinarily equal the pore-volume. The water in the capillary spaces may be that which is retained after thorough wetting from above, or it may have crept upward or laterally from points completely saturated. Capillary movement occurs in all directions, but it is most marked from below upward to points where water is being withdrawn by evaporation or by the demands of growing vegetation.

The height to which water may rise by virtue of this force depends upon the diameter of the spaces; the smaller the diameter, the greater the rise. Jurin's law of capillary movement is, that the height of ascent of one and the same liquid in a capillary tube is inversely as the diameter of the tube. Thus, water will ascend ten times as high in a tube having a diameter of 0.1 mm. as it will in another with a diameter of 1.0 mm. It follows, therefore, that capillary movement is most marked in soils of fine texture.

Capillary movement is influenced materially also by temperature and by the nature of substances held in solution. It diminishes as the

temperature rises, and increases as the temperature falls, so that cooling a soil uniformly will cause increased capillary movement, and heating it will cause a fall. But with uneven temperatures, the motion will be different according as the temperatures vary. Thus, if the lower part of a column of soil be cooled, the surface tension of its contained water will be increased at that point, and water will be attracted from the parts above, gravity assisting; whereas, if it be heated, its contained water will be attracted upward.

In saturated soils, motion of the water in any direction is influenced very greatly by temperature, because of the effect of heat in changing the viscosity of water. The higher the temperature, the greater the diminution in viscosity and the freer the movement.

The influence of dissolved substances depends upon their nature, some favoring, and others retarding, movement. The rate is increased by the presence of nitrates, and is diminished by common salt and sulphate of calcium; but the favoring influence of the presence of nitrates is counteracted most markedly by organic substances produced in the decomposition of matters of vegetable origin, for a minute trace of these completely neutralizes the effect of such amounts of the former as are commonly present in cultivated soil.

It is self-evident that anything tending to the diminution of capillarity of a soil diminishes the rate of capillary flow. When the soil is worked in such a way, therefore, as to produce an open, crumbly condition in place of one of compactness, the rate of capillary movement within it is diminished very greatly.

We come now to the third division, which has been designated as gravitation-water. This is the water which has drained away through the soil by the force of gravity and accumulated in the subsoil over an impermeable stratum which has arrested its farther downward journey. This is what is commonly known as ground-water, or subsoil-water. Its zone extends from the surface of the impermeable barrier upward to that point where the interstices of the soil cease to be completely filled with water, but are filled partly with air. This point is known as the ground-water level. The zone above it, through which water is moved in the capillary spaces, is known as that of the capillary soil-water, and extends as far as the water is moved through that force. Above this, at and near the surface, is the zone of evaporation, from which water is evaporated into the atmosphere.

The impermeable stratum beneath the subsoil-water may be either very fine sand, compact clay, or rock. It may be thin or thick, according to circumstances. Below it, there may be a succession of alternating permeable and impermeable strata, so that in driving deep wells a variety of strata are pierced, and waters of varying composition may be secured. Dense clay is practically impermeable to water, but at the same time it can communicate its moisture to surfaces with which it comes in immediate contact, a fact which renders necessary the interposition of damp-proof material in the foundations of houses built upon it.

Rocks vary greatly in impermeability; the densest of them contain very small amounts of moisture in their pores, while others are so porous that they may contain as much as a third of their volume of water. Again, most rock deposits are more or less fissured and seamed, and thus permit to a greater or less degree the passage of water at these points.

The water-bearing stratum is usually gravel or sand, but may be porous or fissured rock. Its depth is exceedingly variable, depending upon local geological conditions, and at two points not widely separated, it may be respectively slight and considerable.

The ground-water is in constant motion both laterally and vertically. Its lateral movement, whatever its rate, depends upon the configuration of the impermeable layer below, and not upon that of the surface of the land. Generally speaking, the direction of the movement is toward the nearest large body of water, be this the sea, a lake, or a river; but it is not often possible to determine, except in a general way, from surface observations, whether at any given point the flow is in one direction or another. This is especially true when the water-bearing stratum is thin and underlaid by an impermeable stratum of very irregular conformation.

The rate of movement is also exceedingly variable; it may be fast, or slow, or hardly perceptible. In Munich, for instance, according to Pettenkofer, it amounts to about fifteen feet daily, while at Berlin, it is only very slight, and at times is wanting. It is influenced by the configuration of the subsurface, by the permeability of the subsoil, by the amount of the accession of moisture from rainfall and melting snow, by the obstacles interposed by the roots of trees and other plants, by others at its outfall, and by the withdrawal of moisture by the needs of vegetation and of communities of men.

The rise and fall of the ground-water—that is, its vertical movement—depend chiefly upon the amount of rainfall; and, on the other hand, upon the rate of withdrawal by evaporation, vegetation, and water supply of communities, and upon the freedom of, or obstacles to, the outflow.

The effect of rainfall is generally not immediately perceptible, for so much time intervenes between heavy falls and penetration that a falling of the ground-water level may continue to be observed for a long time after a period of great wetness; but when the level rises, it is a proof that additions have been received from above, though perhaps the accession has travelled through a long distance in the soil. When the level falls, it is a sign that the upper strata have become dry through evaporation, and that capillary attraction has carried moisture upward to replace the loss.

The rise and fall of the ground-water level may be determined by measuring from day to day the distance between the surface of the soil and the height of the water in a number of wells in a given locality. This may readily be done by means of a tape-measure or chain to which

is attached a rod bearing a number of shallow metallic cups which are lowered into the water. The distance between the point on the chain at the mouth of the well and the uppermost cup in which water is found indicates the position of the water-level with respect to the surface.

By removing obstacles to the outfall of the underground river as it sometimes is called, and by creating new outfalls by ditching more or less deeply, according to individual conditions, by sinking drainage wells, or by laying drain tile beneath the surface at such depths as may appear to be advisable, the level of the ground-water may be considerably lowered, and the soil thereby rendered correspondingly drier, and also, by reason of the influence of water on soil temperature, warmer.

Sources of Soil-water.—The principal source of soil-water, it is hardly necessary to say, is the rainfall, but by no means all of the water precipitated from the atmosphere during a storm penetrates to the subsoil. Light rains may be wholly lost by evaporation, and heavier ones, especially during active vegetation, may penetrate but very slightly beneath the surface. In early spring and in autumn, the amount which percolates downward is naturally much larger in proportion. A by no means insignificant amount of moisture is that derived by absorption and condensation from a moist atmosphere. In periods of drought, this power of dry soil to absorb water from humid air is of the greatest value to vegetation. The amount absorbed differs according to the nature and hygroscopicity of the soil elements. Thus, a soil rich in humus will attract more water than another composed wholly of sand. Condensation of water occurs when the surface is cold and in contact with moist air. This condensation may occur from above or from the rising moist soil air just below.

A third source of moisture, of no great importance, is the breaking up of organic matter into its constituent elements, in which process the hydrogen is in great part ultimately released in combination with oxygen as water. Another and exceedingly important source of soil moisture, important not because of the amount, but because of the quality of the water, and because of its possible effect on the supply of drinking-water and on public health, is the waste waters incident to human life, which in so great a proportion of communities are discharged directly into the soil, where, being out of sight, they are equally out of mind.

Loss of Soil Moisture by Evaporation.—The amount of water which a soil loses by evaporation is influenced by a number of factors, which include the water content of the soil, the height of the permeable layer, the composition and structure of the soil, and the character of its surface, and, particularly, whether it is covered. In other words, the rapidity of the process is proportional to the combined area of surfaces exposed, and to the facility for replacing the loss by withdrawals from below.

Influence of Vegetation on Soil Moisture.—The amount of water in soils is influenced greatly by growing vegetation, which requires a vast supply for the proper maintenance of its functions. It withdraws it by absorption by the roots, which extend downward to surprising depths, the roots of wheat, for instance, attaining sometimes a length of eight feet and more. From the roots, the water passes into the circulation of the plant, assists in the various physiological processes, and then, for the most part, is given off from the leaves into the atmosphere. It has been calculated by Pettenkofer that an oak evaporates more than eight times the rainfall, and that the *Eucalyptus globulus* is even more active. The difference between the rainfall's contribution and the amount exhaled represents the amount which has been withdrawn by the roots from the capillary spaces and from the water-table itself. As the water in the capillaries is relinquished by them, more comes up from below to take its place. Thus it is that a plant or tree acts during the growing season as a constantly working suction apparatus tending to dry the ground, and so may be explained, in part at least, the condition of wetness that is acquired by some lands after removal of trees.

All growing crops withdraw enormous amounts of water, and after the growth becomes well advanced, it is the capillary water upon which dependence is placed, for the rainfall penetrates but a short distance into cultivated land, and most of it is lost by evaporation. Were it not for the capillary water supply, no crops could be raised, except under most extraordinary conditions of weather and by artificial irrigation, since but a short period of drought would suffice to produce wilting. According to Stockbridge,[1] "The quantity of water thus required and evaporated by different agricultural plants during the period of growth has been found to be as follows:

1 acre of wheat exhales	409,832	pounds of water.
1 " " clover exhales	1,096,234	" " "
1 " " sunflowers exhales	12,585,994	" " "
1 " " cabbage exhales	5,049,194	" " "
1 " " grape-vines exhales	730,733	" " "
1 " " hops exhales	4,445,021	" " "

But the influence of vegetation on the water content of the soil is not limited simply to its withdrawal and evaporation into the atmosphere, for it acts in the other direction to impede surface flow and subsurface drainage. This is seen more particularly in the case of trees and forests. The forest cover keeps the soil granular and promotes downward percolation; the tree roots, penetrating in all directions, present an effective obstacle to rapid lateral movement through the soil. Removal of forests and clearing away the surface of the forest litter promote sudden and destructive freshets in the springtime and drought when, later in the year, the water is needed. The ill effects of deforestation are noticed particularly in parts of Maine and in the Adirondacks, where streams that formerly ran full the year round are raging

[1] Rocks and Soils, New York, 1888.

torrents when the winter's snows are melting and but insignificant brooks or wholly dry during the summer months. It has been stated by Major Raymond, of the U. S. Engineers, that, in forest areas, four-fifths of the rainfall are saved, while in cleared land the same amount is lost by evaporation and surface flow.

Other Effects of Vegetation Upon the Soil.—In addition to its influence on the movement of soil-water and on its amount, vegetation is an important factor in the determination of soil temperature and of the amount of mineral matter available for succeeding growths. The deeply penetrating roots bring to the tissues of the growing plants a large amount of mineral matters from the subsoil. On the death and decay of the plant, these matters are returned to the soil at its surface, where they are available for reabsorption as plant food.

The effect of vegetation on soil temperature is of much importance in both hot and cold climates. A barren soil or one from which vegetation has been stripped absorbs the heat rays of the sun more rapidly and becomes much hotter than one which is protected by growth of any kind. The air above the soil becomes hotter, too, because of greater heat radiation, and the difference in the surface temperature of bare ground and that covered by grass or other vegetation is further increased by the cooling effect of evaporation of moisture from the leaves. Herbage acts as a protection against excessive heating in hot climates, and as a blanket to prevent loss of heat in cold ones. In summer, the areas covered by vegetation are cooler than those which are unprotected against the direct rays of the sun, and in winter, they are warmer because of the obstacle to heat loss.

Trees obstruct the sun's rays and impede wind currents, and thus the soil is cooler and at the same time suffers less loss of moisture by evaporation. The obstruction of the wind currents deprives the soil air of one of the influences having to do with its movement, and thus interferes with soil respiration. The obstacle opposed by trees to the motion of air is so great that, in the interior of a piece of woods, the air may be quite calm while a gale is blowing outside. In winter, the obstruction of the sun's rays aids in the conservation of the soil heat by preventing the accumulated snow from melting, and thus keeps the surface protected by a blanket.

In cold climates the influence of trees may be at the same time pernicious and beneficial; that is to say, pernicious, in that the ground is colder and moister than it would be had the sun's rays free access, and beneficial, in that the trees afford protection against wind. The judicious removal of trees will often render a climate more equable. In hot climates, as in cold, trees should be removed only in case of necessity and after due consideration of the probable results. The hottest spots in hot countries are those deprived of the beneficial influences of vegetation.

It may not be out of place here to mention the supposed agency of woodland in protecting communities from "malarial exhalations" from swamp localities. That the interposition of a belt of trees has been

followed in a number of instances by decided improvement in public health so far as malaria is concerned, cannot well be denied; but the improvement is not owing to the fancied property of leaves to condense upon their surfaces the malarial poison, but to the fact that the winged bearers of this poison, blown along by the wind, are filtered out of the air by the leaves, or themselves seek the protection thus afforded against farther involuntary movements, and attach themselves to the leeward side of leaves and trunks.

Pollution of the Soil.

The soil receives polluting matters of infinite variety and in widely differing amounts, but their nature and their amount are of less importance relatively than their point of entrance. Some of these pollutions are unavoidable, and these, indeed, are the ones concerning which we may give ourselves the least concern; others are avoidable, though not always, or even usually, without the incurring of expense.

The unavoidable pollutions include the urine and droppings of animals, the carcasses of such as have died and have escaped the notice of other animals that act as scavengers, and vegetable matters of every conceivable kind in various stages of decay. Excepting under very unusual conditions, such, for instance, as may exist in time of war or flood or epidemics, when large numbers of horses, cattle, and other animals are killed or die, these, lying at or near the surface, are of comparative unimportance, since, exposed to natural processes of purification, they are resolved into simple innocuous substances, which are absorbed by plant life or washed downward into the soil.

The avoidable pollutions are mainly those which man deposits beneath the surface, and these are first, and of minor importance, the bodies of the dead, and second, of vast importance, the excreta and other organic filth that constitute sewage. The temporary storage of filth in water-tight receptacles built under ground can, of course, do no harm to the surrounding soil, but it is not into such that man usually chooses to deposit his waste. Water-tight cesspools gradually become filled and then require to be emptied, while those with pervious bottoms permit the escape of the contents downward, require no thought or care, and are, therefore, a source of contentment and of saving of expenditure. The filth thus introduced is, however, below the zone of bacterial activity of the beneficent kind, and becomes stored up in the subsoil or is washed away gradually by the ground-water, which thereby is made unfit for human consumption. Organic matters deposited in the upper strata of the soil are resolved into their constituent elements with greater or lesser rapidity according to local conditions of distance from the surface, temperature, degree of moisture, and permeability to air, the process advancing most rapidly in a well-ventilated, moderately dry soil near the surface, and most unfavorably in wet, compact soils, far from the surface.

The influence of the physical condition of the soil is observed fre-

quently in the exhumation of bodies for one cause or another after varying periods of interment. Thus, in open soils, bodies may disappear almost completely in the course of a few years, while in stiff wet clays they may be found even after twenty and more years to be putrid masses, still undergoing a most gradual process of disintegration. Indeed, it is stated that in excavating an ancient churchyard in London, the soil of which was a wet clay, bodies were removed that showed, after two centuries of interment, no materially different appearance from that of others which had been buried not over a score of years. Recently, Dr. A. Riedel[1] had an opportunity to compare the results of decomposition proceeding in bodies buried for about the same period in soils that were respectively loose, well-drained, and well-ventilated, and compact, wet, and impermeable to air. In the first instance, the remains were fairly dry and quite inoffensive to the sense of smell; in the other, they were a slimy, loathsome mass of rottenness, which gave out such a horrible stench that the crowd of idlers that had gathered was quickly dissipated, while those whose duty compelled them to remain were made unpleasantly sick, and could not rid themselves of the smell, which clung to them until several days had elapsed.

In the decomposition of organic substances in the soil, no offensive emanations are noticed, if a substantial layer of earth is interposed between them and the atmosphere. Just as it has power to retain water in its interstices and on the surface of its constituent particles, so has the soil the faculty of absorbing gases and vapors, a property which cannot have escaped the notice of any person acquainted with the common earth-closet. The soil acts in this respect like charcoal, and can take up not only odors, but also coloring matters and other substances.

Perhaps the most striking illustration of the affinity of soil for odors is the fact that illuminating gas from leaking street mains has in its journey through the soil been known to be divested of its odorous constituents to such an extent that, being drawn into houses with the soil-air, its presence escaped observation until the production of poisonous effects drew attention to the existence of an unusual condition of the air.

A like retaining action is manifested in a less marked degree toward substances in solution,[2] which are held back by surface attraction, a fact which has been noted repeatedly by hygienists and agricultural chemists. This is more noticeable in soils of fine grain, since such present a far greater area of grain surface. Hoffmann[3] filled two cylinders of equal size with sand of different degrees of fineness, but with the same total pore-volume, and to each was added from above an equal volume of solution of common salt, and then daily, for ten days, an equal volume of distilled water. The drainage of each day

[1] Münchener medicinishe Wochenschrift, June 6, 1899.

[2] See page 295 for an unusually striking example.

[3] Ueber das Eindringen von Verunreinigungen in Boden und Grundwasser. Archiv für Hygiene, II., p. 145.

was tested as to its content of salt, and it was found that, whereas that from the coarser sand yielded salt on the second day and gave the highest results on the third, from which time the yield progressively dwindled, that from the finer showed no trace until the sixth day, and its maximum on the seventh. Repetition of the experiment in the same way in all particulars yielded identical results. Thus it is shown that pollution travels more quickly in coarse soils than in fine.

In the decomposition of proteid substances in the soil, basic substances are believed by some to be formed, which may be taken into the system, and so affect the resistance of the body to disease as to favor infection. This, however, is purely hypothetical.

As has been remarked, the presence of bacteria is essential for the resolution of organic matters in the soil. This has been illustrated in a striking manner by Duclaux,[1] who treated sterile soil with sterile organic matters, such as milk, sugar, and starch paste, and then planted therein peas and beans. Although the resulting plants were well cared for, they did not thrive, but remained as thin and weak as though growing in distilled water. The organic matters in the soil were of no value in their growth, for they could not be absorbed as such, but only after decomposition. The addition of a little unsterilized earth sufficed, however, to start the required process, and then the growth improved at once.

Bacteria of the Soil.

The bacteria of the soil are found almost wholly in the superficial layers, and below a depth of twelve feet their number is relatively few. As they need organic matter for their growth and multiplication, it may be inferred that the greater the amount present, the greater will be their number. Thus, they are far more numerous in rich garden soil than in ordinary sand and clays.

The conditions most favorable to their development are, in addition to the presence of the organic pabulum, moisture and certain limits of temperature. Dryness and extremes of heat and cold are all unfavorable; saturation with water may or may not be, according to the variety, for there are some that in a wet rich soil can go on decomposing organic matters.

In ordinarily rich soil, the number of bacteria ranges from hundred thousands to millions per cubic centimeter in the surface layers, below which they diminish in number very rapidly, until, at ten to twelve feet below the surface, the soil is practically sterile, except for those that have been washed down or carried by burrowing animals, or, as above stated, deposited by man in organic filth.

The soil bacteria are mainly of the beneficent varieties, the saprophytes which perform only useful offices, including the numerous varieties of the nitrifying organisms. While different species of pathogenic bacteria have been found in the soil, and although certain of

[1] Comptes rendus, C.

them, the bacilli of tetanus and of malignant œdema, are very generally present, this class of organisms finds, as a rule, the conditions present in the soil unfavorable to development.

In the first place, the temperature is too low, excepting in the very uppermost layers in warm weather; and, furthermore, the pathogenic kinds cannot thrive in the presence of the enormously numerous saprophytes, which, in some manner not as yet satisfactorily explained, bring about their destruction. This action has been demonstrated repeatedly by Koch and others, who showed that anthrax bacilli and other pathogenic varieties can grow in sterilized, but not in unsterilized, soil.

Klein[1] insists that pathogenic organisms in buried bodies cannot maintain vitality in the presence of *B. cadaveris sporogenes*, which is always present in decomposing bodies, and that, in most cases, a month is sufficient time to insure destruction. He buried guinea-pigs containing various kinds of micro-organisms within the abdominal cavity, and at different times exhumed them and made search for living specimens. He found that *B. prodigiosus* lived 4 weeks, but not 6; *Staphylococcus aureus*, about the same; *Sp. choleræ*, 19, but not 28 days; *B. typhosus* and *B. diphtheriæ*, not longer than 2 weeks; *B. pestis*, 17, but not 21 days, and *B. tuberculosis*, not 7 weeks.

It is believed that, in the deeper layers, away from the saprophytes, the spores of pathogenic species may find a lodgement favorable to storage, but not to development, and that there they may remain with dormant vitality.

Many examinations of graveyard soils and of bits of coffins have been made by Dr. E. H. Wilson, of Brooklyn, to determine, if possible, the presence of pathogenic bacteria as well as the number of bacteria as compared with those in other kinds of soils. He found no more bacteria than in others, and no pathogenic kinds whatever.

There is one kind of soil that has been found again and again to have a destructive action on pathogenic bacteria, and that is peat, which kills them very quickly, probably through the contained organic acids.

The soil acts as a very good filter, and holds back most of the organisms, but by the aid of flowing ground-water or water entering from above, they may be carried through considerable distances. Thus, Drs. Abba, Orlandi, and Rondelli,[2] experimenting on the filtration capacity of the soil about the filter galleries of the Turin water supply, found that cultures of *Micrococcus prodigiosus*, poured with large volumes of liquid into the ground at various points, made their appearance 200 meters away in 42 hours, and 12 and 27.5 meters away in 7 hours. In these experiments the property of the soil for holding back substances in solution was manifested in a remarkable degree, methyl-eosin and uranin, substances which impart intense red and green coloration to water, and which were added with the cultures, not appearing until

[1] Twenty-eighth Annual Report of the Local Government Board, Supplement.
[2] Zeitschrift für Hygiene und Infectionskrankheiten, XXI., p. 66.

long after the organisms had passed through. In the instance in which they appeared in 42 hours, the coloring agents could not be detected until after 75 hours had elapsed.

The relation of the soil to the various pathogenic bacteria will be discussed farther under separate headings.

Soil and Disease.

The influence of the soil on health and disease is admitted very generally, but is little understood. We know that certain soil conditions favor the occurrence of certain diseases, but why this is so remains a problem for future research to solve.

Our notions concerning the causal relation of the soil are probably greatly in error with respect to certain diseases, being doubtless exaggerated as regards some, and equally undeveloped with others. Composition, permeability, temperature, moisture, evaporation, soil-air, and fluctuations of the level of the subsoil-water, all are supposed to bear important relations to many of the diseases of mankind and of animal life in general.

Such evidence as bears on the relation of the soil to diseases is given in general terms below.

Soil Dampness and Disease in General.—It has long been universally noticed that dampness in and near the surface of the soil injuriously affects the health of those dwelling nearby. It causes coldness of the soil and dampness of the atmosphere immediately above, and appears to conduce more particularly to rheumatism, neuralgias, and diseases of the respiratory tract. It has been noticed by many who have investigated the subject, that the general health of those dwelling over damp soils is much inferior to that of those more favorably circumstanced in that regard, and instances of improvement on removal from damp to dry localities are too commonly known to need illustration.

It is generally agreed that a soil in which the ground-water level is high, five to ten feet, for instance, from the surface, is not favorable to health; and that a deep level, fifteen feet and more, is unobjectionable on the score of dampness. This being admitted, it might reasonably be inferred that artificial lowering of the ground-water will be followed by increase in salubrity, and, as a matter of fact, that is precisely what does occur. But it should be stated, in order to be historically accurate and in all fairness, that while increased healthfulness is a consequence, as a rule it is not the object sought, for, as a general thing, soil drainage, especially on a large scale, has been carried out to meet the demands of successful agriculture rather than in consequence of solicitude for public health.

The methods employed may be stated generally as increasing the outlet and removing obstructions to the outfall. Ditching and the construction of underground channelways by means of drain tile or rubble and fieldstones are the most common methods of drain-

ing. Sometimes, drainage wells are driven at intervals down through the impermeable stratum into an open subsoil, into which they then drain.

The difficulties in the way of draining extensive areas of unhealthy and agriculturally unproductive land lie chiefly in the lack of individual coöperation. Such undertakings must necessarily be carried on in a systematic manner, and ought always to be under the direction of some central authority—municipal, state, or national.

By means of under-drainage, thousands and thousands of acres in various parts of this country, notably in Illinois and Indiana, and vast areas of land in England and on the continent, have been converted from unhealthy, malarious, and more or less unproductive tracts, into healthy and richly productive country; but the scheme is not always successful in relieving a locality of disease, especially of malaria, as has been proved in parts of Italy, Australia, and elsewhere.

Soil and Pulmonary Tuberculosis.—There is an undoubted connection between this disease and soil dampness, which is most manifest when one investigates the prevalence of the disease over the same soil before and after soil drainage, by which it will always be found to be diminished. Why this is so we can only conjecture.

We know that dampness is one of a possibly considerable number of factors in producing predisposition to the disease. We know that, other conditions being the same, the disease is far more common on low damp soils than on elevated dry ones. We know also that the disease is comparatively rare in some parts of the earth where the soil is exceptionally dry.

The distribution of the disease and its relation to soil dampness were first brought to public notice by Dr. Henry I. Bowditch,[1] of Boston, at the annual meeting of the Massachusetts Medical Society, in 1862, who submitted two propositions, the results of most extensive investigation, which were, in substance, that dampness of the soil, whether inherent or acquired by reason of proximity of bodies of water, is an exciting cause of consumption, which disease can be checked in its course or even prevented by proper attention to soil conditions. Shortly afterward, similar conclusions were promulgated in England by Dr. Buchanan, who had been making observations along the same line, not knowing that Dr. Bowditch was similarly engaged. These propositions were accepted by the profession, and have been maintained ever since.

Typhoid Fever.—It is believed quite generally that this disease is connected in some way with soil conditions as well as with drinking-water. Indeed, there are some authorities who regard the soil as of infinitely greater importance in the causation of epidemics of this disease and of cholera than drinking-water, which to their minds has absolutely no influence one way or another. The Pettenkofer theory of the cause of these outbreaks attributes it to the soil, from which the

[1] Topographical Distribution and Local Origin of Consumption in Massachusetts. Transactions, 1862.

exciting cause is distributed by the ground air, which, as has been stated, is in constant movement.

According to the distinguished originator of the soil theory, the unknown poison is introduced into the soil, where, under proper conditions of organic filth, and other influences, a species of fermentation occurs, the end product of which is the exciting cause, which is then capable of inducing the disease in those by whom it is inhaled. All important in this process is the vertical movement of the ground-water, and it is certainly true that over a long period of years of observation at Munich, there was a most remarkable coincidence between epidemics of typhoid fever and fluctuations in the ground-water level.

The condition most favorable to high morbidity was demonstrated to be a rapid fall after an unusually high level. The highest death-rates during the time covered occurred during the years of lowest level, and the lowest rates in the years of the highest level. A similar coincidence has been noticed elsewhere, but by no means in all or even a majority of the localities where investigations have been made.

The theory had, for a time, many adherents, and the controversy between the soil-theorists and the "water-fanatics," as Pettenkofer called them, was carried on at times with exceeding bitterness. But within the past decade, the water theory has been so thoroughly proved as the chief, if not the sole cause of extensive outbreaks, that interest in the theory has fallen off, and its supporters are now few in number. Pettenkofer[1] himself, however, was to the end as uncompromising as in the beginning, and found no difficulty in applying it to the great epidemic of cholera in Hamburg, in 1892.

The contention that the extraordinary endemicity that prevailed so long at Munich was due to the filthiness of the subsoil, which was honeycombed with cesspools, cannot lightly be brushed aside, for it is a fact that, with discontinuance of these abominations, and with a system of improved sewerage, the typhoid fever rate fell from its position as a leader down among the lowest known. Nor was this fall due, as has been claimed, to change in the water supply, for the great epidemics had ceased, and the fall had long continued, before the water supply was changed.

Experiment has shown that the typhoid organism may retain its vitality in the soil for considerable periods under favoring conditions of warmth and moisture. Robertson[2] removed sods from several places in a field, and wet the exposed soil with diluted typhoid cultures, one at the surface, one at a depth of nine inches, and a third at eighteen inches. After 130 days, the bacilli on the surface had multiplied, and where they had been placed eighteen inches below, they could also be found in the surface layer. Later on, in the winter, no results could be obtained; but in the spring, he moistened the patches with sterile bouillon in very dilute condition, and afterward succeeded in obtaining growths.

[1] Münchener medicinische Wochenschrift, May 2, 1899.
[2] British Medical Journal, Jan. 8, 1898.

This positive result accords with the views of Germano,[1] who found that typhoid bacilli will live for months when incompletely dry; but according to Flügge, they do not survive complete drying longer than fifteen days. In air-dried condition they appear to have unimpaired vitality for some days, according to Brownlee,[2] who dried and sterilized ordinary soil and then infected it with a broth culture of typhoid and kept it at 98° F. for a day. It was then left exposed to the air for a week, during which time it became sufficiently dry to be easily scattered by the breath. Cultures from this gave positive results. But it should be remembered that air-dried soil contains considerable hygroscopic water; consequently his bacilli were doubtless fairly well supplied with the necessary moisture. Of more importance, apparently, than the question of moisture—for all soils possess some—is the nature of the contained organic matter. Dr. Sidney Martin[3] has shown that unpolluted (virgin) soils are inimical to the typhoid bacillus, regardless of the amount of their contained organic matter of vegetable origin, while specimens containing polluting material of animal origin favor its existence. Such, after sterilization, were planted successfully, and it was learned that, in the presence of moisture, differences in temperature had but little influence. Thus, the organism thrived about equally well when specimens were kept at 98° F., at ordinary room temperature, and as low as 37° F. By no means the least interesting observation made was with regard to the duration of viability of the bacillus. In one of the sterilized polluted soils, the organism was still active at the expiration of 456 days; and even then, after thorough drying and pulverization, active growth could be obtained. In company with various species of bacteria, among which the predominant kinds were members of the *B. coli* group, it was recovered after 50 days' exposure to temperatures ranging between 37° and 61° F.

Later experiments,[4] in which the typhoid organism was planted with different soil bacteria, proved that various species from a particular soil had the power of completely exterminating it within a short time, while others had no influence whatever. Therefore, it would appear, whether or not the typhoid organism can exist in a given soil, will depend upon the kinds of soil bacteria present, as well as upon special conditions of temperature and dampness. Dr. Martin found the period of vitality in unsterilized soils to be about 12 days, but in no case did the organism appear to multiply. An experiment conducted by Levy and Kayser[5] to determine the duration of infectivity of this organism yielded most interesting results. The feces of a typhoid patient were discharged into a cemented vault, remained therein 5 months, and were then spread on a clay soil, from which, after 15 days of winter weather, the specific organism was isolated. They came to the natural conclusion that

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXIV., p. 403.
[2] Public Health, January, 1899, p. 272.
[3] Report of Local Government Board, 1898, London, 1899.
[4] Ibidem, 1900, London, 1901.
[5] Centralblatt für Bakteriologie, etc., March 20, 1903, Abth. I., XXXIII., p. 489.

typhoid stools ought always to be disinfected before being discharged into a privy vault.

The effect of temperature changes due to the presence of animal excreta mixed with the soil is shown by Gaertner[1] to be considerable. He introduced cultures of various organisms in wire baskets into the interior of compost heaps of various composition, which became heated to different extents, and observed that the bacilli of typhoid and cholera were the least resistant of all. With rapid and marked heating, their life was short; but it appears probable that in the absence of heat, even with the given surroundings, they may live through the winter. Under the ordinary heating that occurred in the compost, these two organisms were destroyed in a week, while the bacillus of tuberculosis remained virulent a number of months.

But aside from what we glean from scientific research with the specific organisms, we know from experience that there are many places with polluted soils where typhoid fever was unknown until the importation of a single case from without, and that, afterward, sporadic cases, for which no convincing explanation is afforded, have occurred at varying intervals. And in country districts, whose inhabitants are not given to travelling much beyond the confines of their farms, it is noticed frequently that single cases occur in the same household at intervals of a year or longer.

In such cases, it seems hardly reasonable to say that the original case has left nothing as the exciting cause for later attacks, and that fresh introductions of the specific organism must have occurred from some unknown source, for it is not unlikely that the variety of conditions that affect the viability of the organism may, in some cases, act to keep it alive, and, on occasions, stimulate it into a condition of augmented activity.

Cholera.—Concerning the relation of this disease to the soil, there is but little to be said. Prior to the discovery of the specific organism, the soil theory of the origin of epidemic outbreaks had considerable vogue; but now it is known that, even in times of greatest prevalence of the disease, the organism has never been found under natural conditions in the soil. It can be kept alive under certain favorable conditions of moisture and heat for varying periods; but under natural conditions it is one of the least resistant bacteria and quickly dies. We have no evidence whatever that cholera is a soil disease.

Bubonic Plague.—This has been regarded as a soil disease; and it has been believed, from the fact that rats have been conspicuous as victims of it in the early stages of its devastating outbreaks, that these animals have acquired the infection in the soil, and have brought it to the surface, and thus acted as its carriers. But rats are notorious as frequenters of places where filth of all kinds accumulates, and it is not strange that where they and filth abound, they become diseased, if the infective agent is present.

The tremendous epidemics that have raged within the past few years

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXVIII., p. 1.

presented unusual opportunities for extensive study, which thus far has afforded no evidence whatever that the disease is soil-borne. Some who have studied the disease in India believe that soil conditions are responsible for the localizing tendency that is frequently observed, and that infection occurs through skin abrasions, which, in great numbers of the population, exist in chronic form, on account of the prevalent custom of wearing toe-rings and going barefoot. Others deny that infection occurs in this manner, and assert, moreover, that the plague bacillus cannot long survive in the soil. Yokote,[1] for instance, buried mice dead of plague, and determined by successive removals and examination that the organisms survived not longer than 1 month. The soil in immediate contact did not become specifically infected.

Diphtheria.—Although there is no proof that the bacillus of diphtheria is found even as an occasional lodger in the soil, there is a general agreement that a close connection exists between soil dampness and the prevalence of this disease. It is true that experiment has demonstrated the viability of the organism in moist soils for limited periods, but it has never been found in soils other than those in which it was deposited intentionally. The common belief is that a moist soil is an invariable concomitant of unusual prevalence, and that in times of comparative freedom from the disease, the soil is dry and the level of the ground-water low. "As long as the soil is well washed by the winter's high tide and afterwards dried and aërated during the summer's low tide, all goes well: but so soon as these salutary movements are arrested or their order disturbed, diphtheria prevails, reaching its acme of prevalence when stagnation at a relatively high level is most complete."[2]

According to Dr. S. M. Copeman,[3] there appears to be no direct relation between epidemics and rise or fall of the ground-water, "provided that the structure and atmosphere of the houses are not affected. Many districts, which, usually dry, are liable to occasional floods, are remarkably free from the disease, so that it appears that a persistent impregnation of the soil with moisture is of more importance than fluctuations in the height of the ground-water, particularly if these have any considerable range."

Opposed to the views above expressed are the conclusions based on a most careful and extensive investigation by Dr. Arthur Newsholme,[4] of epidemics of diphtheria in all civilized countries and their incident conditions of rainfall and soil moisture. Dr. Newsholme's eminence as a skilful interpreter of the value of statistics, and the fact that no such exhaustive inquiry into this question has ever before been made, entitle his conclusions to more than ordinary weight. Admitting that personal infection is the chief means by which diphtheria is spread from town to town, and from country to country, he summarizes his obser-

[1] Centralblatt für Bakteriologie, Abth. I., XXIII., p. 1030.
[2] Notter and Firth, Treatise on Hygiene, 1896, p. 463.
[3] Stevenson and Murphy, Treatise on Hygiene, 1892, Vol. I., p. 338.
[4] The Origin and Spread of Pandemic Diphtheria, London, 1898.

vations on the relation between rainfall and ground-water and the origin of epidemic diphtheria as follows:

"1. An epidemic of diphtheria never originates, in the towns and countries in which I have been able to collect facts, when there has been a series of years in which each year's rainfall is above the average amount.

"2. An epidemic of diphtheria never originates or continues in a wet year (*i. e.*, a year in which the total annual rainfall is materially above the average amount), unless this wet year follows on two or more dry years immediately preceding it.

"3. The epidemics of diphtheria, for which accurate data are available, have all originated in dry years (*i. e.*, years in which the total annual rainfall is materially below the average amount).

"4. The greatest and most extensive epidemics of diphtheria have occurred when there have been four or five consecutive dry years, the epidemic sometimes starting near the beginning of this series, at other times not until near its end.

"5. Dry years imply low ground-water, and we find, therefore, in the years of epidemic diphtheria that the ground-water is exceptionally low. The exact variations in the ground-water which most favor epidemic diphtheria cannot, with the data to hand, as yet be stated; but it is probable that when this is cleared up it will become clear why in exceptional years which have a deficient rainfall epidemic diphtheria is either absent or but slight."

It has often been pointed out that local soil conditions causing dampness of habitations even in dry years, such dampness, for instance, as obtains in houses built over wet impervious clays, conduce to outbreaks of diphtheria in the dwellers therein; but, as is well known, such dampness acts as a very important depressant of the vital forces, and prepares the mucous membranes of the respiratory tract for the favorable reception of specific organisms of various kinds.

Malaria.—It has ever been held that the most intimate relation exists between the soil and malaria, especially prominent in districts abounding in marsh lands. It has been noticed repeatedly that in malarious countries the upturning and excavation of wet or damp soil are commonly followed by the occurrence of the disease among the laborers so engaged; that infection is more common among those who go about at night, and especially among those who sleep out-of-doors; and that the draining of marsh lands is often followed by the disappearance of the disease. All of these facts are compatible with the theory of transmission by mosquitoes, and it is now accepted generally that malaria is connected with soil conditions only in so far as the latter permit the breeding of the specific mosquitoes. (See Chapter XII.)

Yellow Fever.—There is no evidence of connection between the soil and outbreaks of yellow fever, although for many years such a relation was assumed to exist. The work of American investigators has proved this disease, also, to be mosquito-borne.

Tetanus and Malignant Œdema.—It is well known that the organisms of these two diseases are found very commonly in most garden soils, in road dust, and in soil in general which has been enriched by the addition of decomposing organic matter. But in spite of the fact that opportunity for infection through abrasions, cuts, and wounds of the hands, feet, and other parts is a matter of daily occurrence with a large proportion of the people, these diseases are comparatively uncommon. They are noticed most commonly in cases of severe injuries, such as compound fractures, and in shattering wounds due to explosives. According to some authorities inoculation of spores alone is without effect.

An unusual number of cases of tetanus is noticed in various localities in this country after every annual celebration of Independence Day, due chiefly to wounds caused by cannon-crackers and blank cartridges fired in toy pistols. In 1903, for example, there were in the country at large, according to statistics compiled by the *Journal of the American Medical Association*, no fewer than 415 cases of tetanus from these injuries. In 1904 the number reported fell to 105. Examination of cannon-crackers by Dr. Harold Walker and of blank cartridges by Dr. H. G. Wells for tetanus organisms have yielded negative results, and it is probable that infection is due to organisms already on the hand of the celebrant when the accident occurs.

Anthrax.—The bacillus of anthrax has been found in the soil of pastures in which infected animals have been confined, and it was thought at one time that, following the burying of animals dead with the disease, the soil could be infected thoroughly through spore formation, the spores being brought to the surface by earthworms, there to be the cause of fresh infections. Now, however, this view is regarded as untenable, since the spores are not formed within the putrefying carcass, and the bacillus itself is soon destroyed in the process of decomposition of the tissues. Thus when a body is buried, the organisms are soon rendered incapable of reproduction or of continuing their own existence.

The theory that the spores are brought to the surface by burrowing earthworms, was demolished by Koch,[2] whose conclusions were based upon direct experiment, and was abandoned by Pasteur himself, who first suggested it because of finding spores in the superficial layer of soil at a spot where, two years previously, a cow, dead of the disease, had been buried at a depth of over two meters, a depth not ordinarily reached by earthworms in their burrowing.

Therefore, it seems most likely that fresh outbreaks among cattle grazing on fields where others have died and have been buried are due not to the buried organisms, but to those which in one way or another, from the blood or dejecta of former cases, have been deposited on the surface. We have no evidence whatever that man is even occasionally infected directly with the disease from the soil.

[1] Medical News, June 1, 1901, p. 854.
[2] Mittheilungen aus dem kaiserlichen Gesundheitsamte, 1881.

Uncinariasis.—The disease which stands forth pre-eminently as a true soil-disease, concerning whose etiology there is no dispute, is uncinariasis or hook-worm disease, known also as ankylostomiasis, miners' anæmia, brickmakers' disease, Egyptian chlorosis, and St. Gothard tunnel disease. It was first brought to public notice in 1879 by Perroncito, who investigated the epidemic which occurred among the workmen engaged in driving the St. Gothard tunnel, and discovered the cause of the profound anæmia to be the parasite *Ankylostomum duodenale*, which is a worm about half an inch in length, which attaches itself, sometimes in enormous numbers, to the villi of the upper portion of the small intestine, through which a constant drain is made on the blood. Not until recent years, however, has the disease attracted the attention that its importance deserves, although it has long been known to be very prevalent in Brazil, Egypt, India, and various parts of Europe, and especially in mining districts and brickfields, whence the names "miners' anæmia" and "brickmakers' disease." In 1900, Dr. Bailey K. Ashford[1] made known its presence in the West Indies and brought it to notice as the cause of the tropical anæmia, which, in Porto Rico, causes great misery and an enormous death-rate; and in 1902, Dr. Charles Wardell Stiles[2] announced that, in some parts of the South, it is the most common disease of man, and that it is more prevalent on the farms and plantations of the sand district than in the mining districts. Stiles discovered that, in this country, it is due to a species of ankylostomum, not before described and not found in the Old World, which differs in some important respects from *Ankylostomum duodenale* (*Uncinaria duodenalis*), but produces the same effects. This parasite he named *Uncinaria Americana*. Shortly after this announcement by Stiles, Harris[3] reported that a study of malaria in Southern Georgia and Florida, in a region where profound anæmia is most common, proved that, instead of malaria, he had to deal with uncinariasis, the sufferers showing generally no malaria parasites, but being almost invariably infested with hook-worms. In 1903, Ashford and King[4] declared uncinariasis to be the great scourge of fully 90 per cent. of the agricultural laboring classes (about 600,000 persons) of Porto Rico. As an indication of its prevalence in the South, the experience of Dr. L. M. Warfield[5] is of great interest. He examined 60 boys, inmates of an orphanage near Savannah, and found that no fewer than 48 were infested. Dr. Claude A. Smith,[6] speaking of its prevalence in the South, says: "It seems as though the entire country was literally saturated with it. It is found on the highlands as well as on the lowlands, and on the mountains as well as on the seaboard."

[1] New York Medical Journal, April 14, 1900.
[2] Public Health Reports, October 24, 1902.
[3] American Medicine, November 15, 1902.
[4] Ibidem, September 5, 1903.
[5] Ibidem, January 9, 1904.
[6] Journal of the American Medical Association, August 27, 1904.

Within recent years the disease has been found to exist in many parts of Europe (England, Belgium, Hungary, Germany), where its presence never before was suspected, but the victims have been chiefly miners, and the disease has been regarded as peculiar to coal-mining and other underground occupations. The fact that this is no more the case in Europe than in this country is shown by the observations of the Drs. Iberer,[1] who examined large numbers of peasant lads, who never had worked in the mines, but who, nevertheless, yielded in many instances large numbers of the parasites, which fact leads to the conclusion that the disease is endemic on the farms. Many of these young men after an absence of 3 years, during which time they were doing military service, were found to be still infested; but they had, nevertheless, suffered in no way in consequence. Of the miners examined, no less than 94 per cent. yielded the parasites, and yet no more than one-fourth were even temporarily incapacitated.

So long ago as 1895 the disease was declared by Thornhill[2] to be far more serious in India, Assam, and Ceylon than cholera, on account of the vast number of people affected and the aggregate direct and indirect mortality. He called attention to the fact that, instead of uncinariasis, anæmia, debility, dropsy, malarial cachexia, and diarrhœa were given as diagnoses. This is of especial interest when we read that, in the district studied by him, Harris has shown that most cases of malaria prove to be uncinariasis. The disease is essentially one of the poor, and its spread is due to the habit of discharging feces upon the surface of the ground. The eggs of the parasite are produced in great numbers and escape with the feces. Deposited on moist soil, they hatch in about 24 hours, and the embryos, after twice shedding their skin, are ready in from 4 to 5 weeks to infest man. Baker[3] accounts for the prevalence of the disease by the habits of the people where it is most common. They live without regard to ordinary sanitation; they are dirty in their habits; they discharge their feces wherever they happen to be; they eat with dirty hands, and often eat the dirt itself. Ashford and King say that, in the parts of Porto Rico where the disease prevails, there are practically no privy vaults, and a bit of soil as large as a pea may contain as many as 50 larvæ.

While it is generally accepted that the chief portal of infection is the mouth, to which the parasites are conveyed on food contaminated by dirty fingers or by dirty dishes, or on unwashed vegetables or fruits likely to be spattered with mud, or perhaps in muddy water, there appears to be ground for the belief that a large proportion of cases are due to infection of the skin. The first to assert that the parasites can reach the intestine through the skin was Looss,[4] who rubbed the larvæ

[1] Münchener medicinische Wochenschrift, 1903, No. 22, p. 992.
[2] Indian Medical Gazette, September, 1895, p. 339.
[3] British Medical Journal, March 28, 1903.
[4] Centralblatt für Bakteriologie, etc., 1 Abt. XXIX., p. 733; XXXIII., Orig., p. 330.

into the backs of puppies and later found that the animals contained the parasites within their intestines.

Boycott and Haldane[1] believe that infection can occur through the skin, and Smith[2] appears to have proved it. He bound some earth containing 4-day-old larvæ to a man's wrist and allowed it to remain in contact for 1 hour. Almost at once the spot began to itch and tingle. The stools, which were examined at the time with negative results, were examined twice each week thereafter and continued to be normal until the middle of the seventh week, when eggs began to appear. In a prior communication[3] he asserted that ground-itch is the most common disease in the South, due to the habit of going barefoot; and Warfield[4] states that of the 48 boys in whom he found the parasite, 45 gave a history of ground-itch. Warfield suggests, however, that the way in which the patients with ground-itch become infected internally is very simple: that they scratch their feet and break the vesicles and thus get the embryos on their fingers, by which they are conveyed to the mouth. But, however it happens, the infecting material comes from the soil. Nicholson and Rankin,[5] also, are of the opinion that ground-itch is the most important factor in the transmission of uncinariasis. They have noted that where there is no ground-itch there is little or no uncinariasis, and that where one is common, the other is also. Nearly every one of a large number of cases studied by them gave a history of ground-itch.

The principal measure of prophylaxis is, naturally, the discontinuance of the practice of polluting the surface of the ground; but it is difficult in all countries to persuade those who have never been accustomed thereto to use latrines of any kind. In a privy-vault, the embryos, which cannot live without air, will speedily die. They are destroyed also by freezing and by complete drying, but soil which is apparently dry often contains considerable moisture. Other preventive measures, which are so obvious as hardly to need mention, include the wearing of shoes, the observance of personal cleanliness, especially of the hands, and discouragement of the habit of dirt-eating.

Goitre.—The various theories connecting individual constituents of the soil with goitre have now been well-nigh universally abandoned, since no one of them has been found to hold good in different localities having the same general soil characteristics. Thus, the magnesian limestone theory, which in some quarters is still in favor, can hardly stand in the face of the fact that, in some vast tracts of such formation, as in parts of New Zealand, for instance, the disease is practically unknown. Similarly, the metallic sulphides escape conviction, for in districts where they abound extensively, the disease may be absent, and in others where they are unknown it may prevail.

[1] Journal of Tropical Hygiene, January 1, 1903.
[2] Journal of the American Medical Association, August 27, 1904.
[3] Ibidem, September 19, 1903.
[4] Loc. cit.
[5] Medical News, November 19, 1904.

Epidemic Diarrhœa.—The great prevalence of diarrhœal diseases, especially among very young children, during the hotter months of the year, has long engaged the attention of sanitarians as a tremendous factor in the always high death-rate of the first age periods; but beyond the observance of a few coincidences, no connection has been proved to exist between it and the soil.

In the investigation of milk supplies in single cases and in groups of cases in single households and in institutions, various very virulent organisms, including *B. enteritidis sporogenes*, have been found, and it is not unlikely that the infective agent, whatever its origin, owes much of its dissemination to being blown about in the dust of the air. Observations made by Drs. Hope, Newsholme, and others indicate that in rainy summers, when the dust is kept down, the incidence of diarrhœa falls notably, and in unusually dry summers it shows a corresponding rise.

Examination of Soils.

The complete examination of a soil includes chemical, physical, and bacteriological determinations, but inasmuch as the chemical analysis, beyond the estimation of water and organic matter, is of no especial interest to the sanitarian, though of great importance to the agricultural chemist, we shall, with the exceptions noted, confine ourselves to the processes involved in the physical and bacteriological tests.

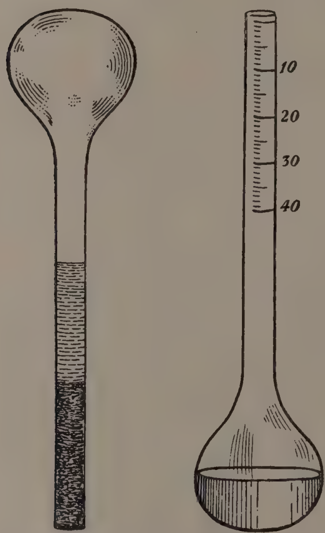
In taking samples, a place should be selected which fairly represents the locality, and under some circumstances a number of specimens should be obtained. These may or may not be mixed and treated as one. About two pounds of the soil may be broken up by being passed through a coarse sieve, then spread out and left for one or several days exposed to the air, and to that extent dried. To determine the relative proportion of the grains of different sizes, a weighed amount of the sample is now passed through a series of sieves of varying coarseness, made of metal or porcelain with circular open spaces, which in each sieve are of uniform diameter. Those used by the German scientists have openings respectively $\frac{1}{3}$, 1, 2, 4, and 7 mm. in diameter, by means of which a specimen is separated into grains of less than $\frac{1}{3}$, from $\frac{1}{3}$ to 1, from 1 to 2, from 2 to 4, from 4 to 7, and over 7 mm. in diameter. Other sized openings may be used, but these fulfil all requirements. The specimen is passed first through the coarsest of the set, and then, in order, down to the finest. If the particles adhere firmly, the separation is done best with the assistance of water; and should it be necessary, a pestle covered at the working end with rubber may also be employed. The separate parts are then dried and weighed, and their respective amounts expressed in percentages of the whole.

The finest particles, that is, those of less than $\frac{1}{3}$ mm., may be separated still further by the process of washing in an elutriating apparatus, of which there are several kinds, none of which, however, gives results that are more than approximately accurate, since so many different

forces and conditions come into play to influence the process. With some, the separation is effected by causing the particles to settle downward through a volume of water, the heaviest ones reaching (theoretically, but not wholly in practice) the bottom first, and the lightest settling out last or remaining a long time in suspension.

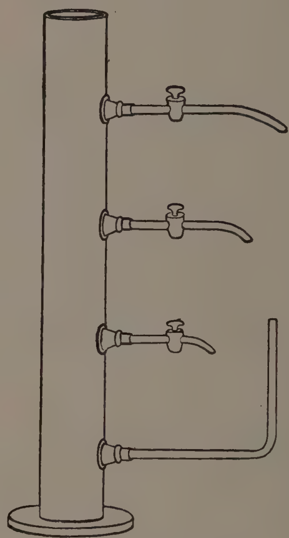
An apparatus of this sort is shown in Fig. 18, which requires no explanation. Another, known as Knop's silt cylinder, is shown in Fig. 19. This is a cylinder carrying lateral tubes fitted with stopcocks, situated at equal distances (10 cm.) apart. The sample is placed in the cylinder, which is then filled with water and well shaken. After a given time the upper stopcock is opened and the water above it is drawn off. Then after the lapse of another interval, the second is opened,

FIG. 18.



Apparatus for separation of fine particles of soil.

FIG. 19.



Knop's silt cylinder.

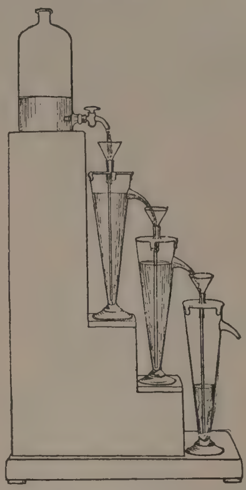
and next, in the same way, the third. The process is repeated until the wash water comes away clear, then the lowest tube is opened, and the rest of the water above the remaining material drawn off. The different portions may then be collected, dried, and weighed, and their relative proportions expressed as before in percentages. Or the residue may be dried and weighed and the remainder estimated by difference.

By another method, the washing is carried out by means of an upward flow of water in a conical vessel, at the bottom of which the sample is placed. The water, delivered through a tube reaching to near the bottom of the vessel, carries the lighter finer particles upward and out through the exit tube near the top. Such an apparatus, known as Schultz's, is shown in Fig. 20.

Pore-volume.—The pore-volume is determined very simply by adding to a volume of water in a graduated cylinder a known volume

of soil in the dry state, and noting the height to which the water rises. If, for instance, to a liter jar containing water up to the 500 cc. mark, we add 500 cc. of dried soil in as nearly as possible its natural state of compactness, and observe that the level of the water is in consequence raised to the 850 cc. mark, it follows that the increase, 350 cc., represents the actual bulk of the soil grains, and that the difference between this and the volume occupied originally by the sample (500 cc.), that is to say, 150 cc., represents the amount of interstitial space filled with air. Then, since 500 cc. of soil contains 150 cc. of air space, it follows that the pore-volume of the sample is x in the equation $500 : 150 :: 100 : x$, or 30 per cent.

FIG. 20.



Schultz's elutriating apparatus.

In order to approximate more closely the natural condition of compactness, the sample may be taken from the soil by means of a metallic cylinder with a cutting edge. It is then dried in order to expel the contained water, which otherwise would constitute a source of error, and is then added to the water in the liter jar as before.

Permeability to Air.—Permeability to air may be determined by forcing measured volumes of air under constant pressure through a cylinder closely packed with the sample, and noting the amount which is delivered during any given unit of time. In making comparison tests between different soils, the same conditions must be observed in every case; that is to say, the length of the column of soil in the cylinder, the pressure employed, and the unit of time. A still farther condition which should be observed, but which is commonly disregarded, is the temperature of the air, for, as is the case with liquids, the viscosity of gases varies with changes in temperature, though not in the same direction. The viscosity of liquids is increased with diminished temperature, whereas in the case of gases the reverse is true. Disregard of this fact leads to important degrees of error.

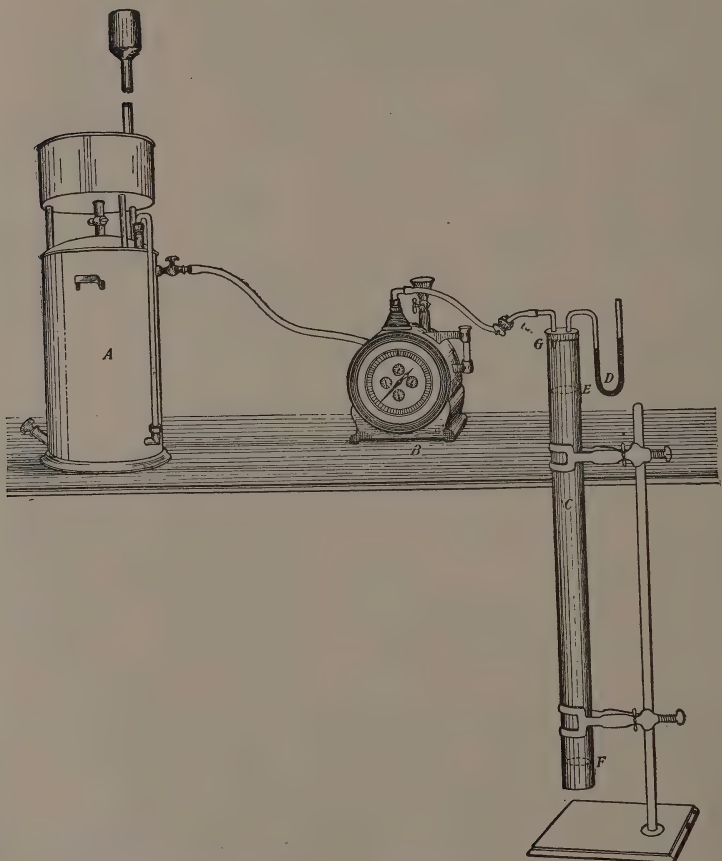
The apparatus for this determination, shown in Fig. 21, comprises a gas-holder (A), a gas-meter (B), and a cylinder (C) provided with a manometer (D). For the purpose of keeping the soil in position, tightly fitting perforated disks (E and F) of metallic gauze are introduced into the cylinder at both ends of the column of soil.

In the preparation of the cylinder, the disk F is first introduced, and then the soil is added a little at a time, and made as compact as possible by striking the lower end of the cylinder downward with reasonable force against the table. When the desired length of column has been reached, the disk E is introduced, between which and the inlet end (G) an air space of sufficient size is left to insure uniform pressure

against the entire surface of the disk. The inlet end is closed by means of a tightly fitting rubber stopper having two perforations, one of which carries the inlet tube from the gas-meter, and the other the manometer indicating the pressure employed.

The pressure is obtained by means of a column of water communicating with the chamber of the gas-holder, which is connected by a rubber tube with the inlet of the meter; and it is regulated by a screw

FIG. 21.



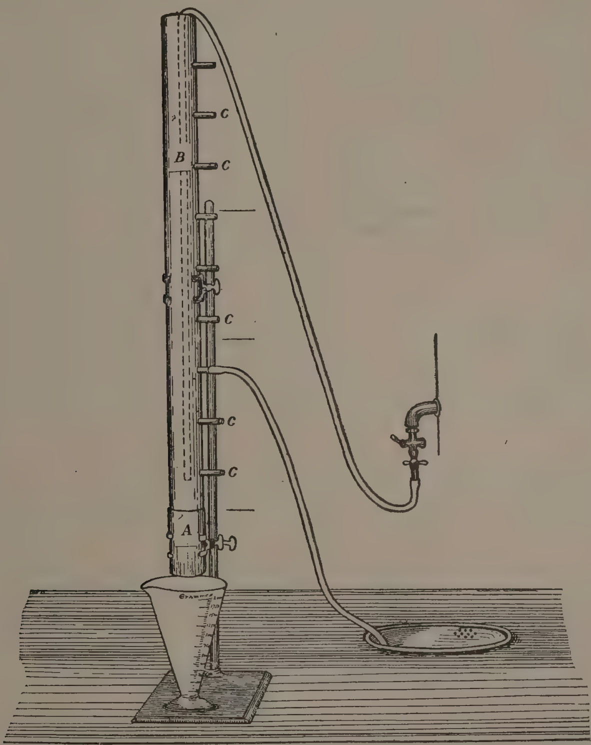
Apparatus for determination of permeability of soil to air.

pinchcock on the outlet tube of the latter. The force is applied, the reading of the meter is noted, and at the expiration of the unit of time, one, five, or whatever number of minutes it may be, the reading of the meter is taken again.

Permeability to Water.—The permeability of a soil to water is expressed in terms indicating the amount of water which will pass from above downward through a column of saturated soil during any

given unit of time under a given pressure. The apparatus for this determination, shown in Fig. 22, consists of a metallic cylinder (A) with a perforated or gauze bottom on which the sample of soil is packed closely, and another cylinder (B), likewise of metal, provided with a number of outlet tubes (c), at regular intervals, preferably of 5 or 10 cm. The lower end of B fits tightly into the upper end of A, and the joint is made impervious to water by means of adhesive plaster, sealing-wax, or other suitable material. The soil within the lower cylinder is kept in place, and its surface kept intact, by means of a

Fig. 22.



Apparatus for determination of permeability of soil to water.

superimposed disk of gauze or coarse cloth. The outlet tubes, provided with cocks, serve to maintain a constant level, and, therefore, a constant pressure of water as desired. Water is admitted in a constant stream to the cylinder through its upper end, by means of a rubber tube connected with a water faucet. If it be desired to employ the highest pressure obtainable with the apparatus, all the corks of the outlet tubes, except the upper one, are kept in place. In this case, the pressure would be expressed by the distance between the top of the soil under investigation and the uppermost outlet, through which the excess of

water from the faucet is allowed to escape, by way of a rubber tube leading to a sink. Similarly, any other height and pressure may be employed by removing the cork of the corresponding outlet, which thus becomes the effluent. Whatever the height maintained, it is necessary to keep the delivery end of the inlet tube below the surface of the water

The process is as follows: Having chosen the pressure and adjusted the waste tube to the proper outlet, the water is allowed to run in and force its way down through the soil until the latter becomes saturated. In order to insure complete saturation, it is best, however, to immerse the soil cylinder, in order that all the air may thereby be displaced upward. When this has been accomplished and water begins to run or drip through the gauze bottom, the time is noted, and the discharged water is received in a suitable graduate. At the expiration of the unit of time, the latter is removed and its contents measured. The experiment may be repeated as often as may seem advisable, and the effects of varying pressures may also be determined.

Water Capacity.—The power to hold water is determined by means of a metallic cylinder of known capacity with a gauze bottom. This is weighed, then filled with the dried sample, and again weighed. The soil next is saturated completely by immersion of the cylinder in water, and then it is allowed to drain as long as water continues to escape. When the water ceases to drain away, the cylinder is wiped dry outside, and the weight of the whole is taken again. The increase in weight is the amount of water retained, and it may be stated in percentage of the pore-volume, which should have been determined previously.

Capillarity.—The height to which water will rise in a column of soil by capillary attraction is determined by packing the sample tightly into a graduated glass tube, the lower open end of which is covered with coarse linen tied securely on, so as not to slip. The tube is supported with its cloth-covered end resting in a shallow dish filled with water, which is kept at constant level. The height to which the water rises through the column of soil is noted from time to time, until ascent ceases. The change in the color of the soil, due to wetting, indicates the progress of the action.

Moisture.—The amount of moisture in a soil is determined most accurately by taking a sample in its natural condition, by means of a brass cylinder with a cutting edge, weighing a portion of it, and then drying it in an air bath at 105° C. until it ceases to lose weight. The difference between the original and final weighings represents the amount of water in the given weight of soil. If it is desired to know the amount of water which the same soil will absorb from a saturated atmosphere, the thoroughly dry sample may next be placed with a dish of water under a bell-glass. The confined air will become saturated with aqueous vapor in a short time, and this will be absorbed by the soil up to the limit of its capacity, which is shown when its weight no longer continues to increase.

The hygroscopic moisture of a soil may be determined roughly by air-drying a sample and then taking a known weight of it and heating it in an air-bath at 105° C.; or by exposing it to a dry atmosphere in a bell-glass containing an open dish of concentrated sulphuric acid, until it ceases to lose weight.

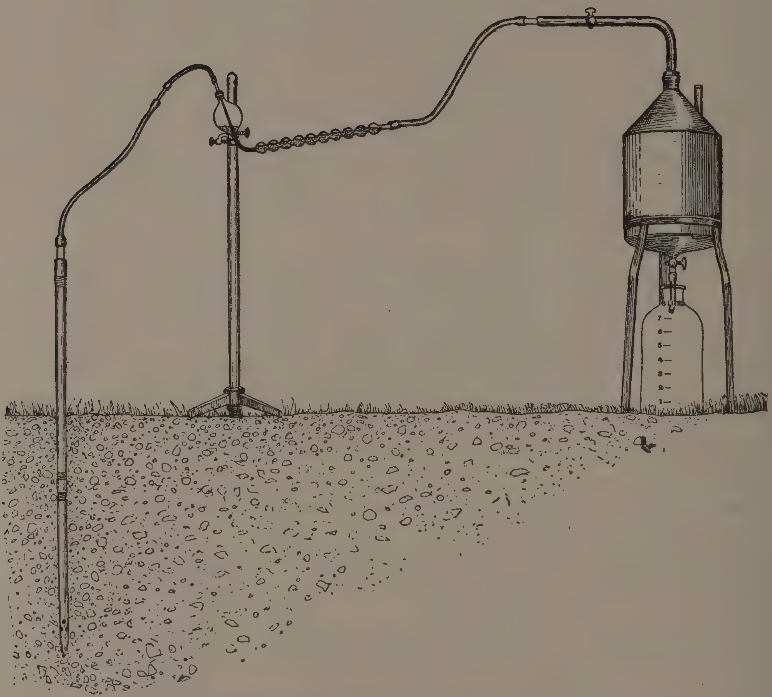
Organic and Volatile Matters.—Since it is impossible to determine by ordinary processes the exact amount of organic matter present in any soil, it is necessary to designate the diminution in weight which occurs on subjecting a sample to such a heat as will burn off the organic matter, and which represents other losses than the latter, as "loss on ignition" or "organic and other volatile matter." For this determination, the soil which was used for the estimation of moisture, or another sample, thoroughly dried, may be placed in a platinum dish and heated over a Bunsen flame at no higher temperature than is sufficient to keep the dish at a dull-red heat. When all the organic matter has been destroyed, the residue is allowed to cool, and is then moistened with a little saturated solution of carbonate of ammonium, in order to restore the carbon dioxide that belongs to the inorganic constituents, then dried and gently ignited to expel the excess of ammonia, and finally weighed. The loss represents organic matter, ammonium salts, nitrates, water of crystallization, etc.

Determination of CO_2 in Soil Air.—The analysis of soil air is conducted upon the same principles as that of ordinary air, but the method employed is necessarily different so far as the obtaining and handling of the sample are concerned. The reagents are the same as required in the analysis of atmospheric air; the apparatus, however, is quite different. It consists of a number of sections of water-pipe with screw joints, one having a pointed foot, above which are a number of perforations within a limited area; an absorption tube, in which the barium hydrate solution is held and through which the air is drawn, and an aspirator. (See Fig. 23.)

The section with the pointed end is driven into the soil, and the pipe is lengthened by the addition of the other sections, so that any desired depth may be reached, and thus the air of any stratum may be withdrawn. The upper extremity is connected by a rubber tube with the inlet tube of the absorption apparatus, which latter may be a plain glass tube about an inch in diameter with a bend of about 130 degrees near one end. Better, however, is the apparatus shown in the illustration. Here the short leg of the bent tube is a large bulb, and the long leg is a series of small bulbs, the communications between which are of small diameter. In either case the inlet tube passes through a tightly fitting rubber stopper and extends to a point just beyond the bend. The other end of this apparatus is connected by means of a rubber tube with the inlet of the aspirator. Any form of aspirator may be used, but preferably one of a capacity of about twenty liters. A measured amount of the dilute solution of barium hydrate, sufficient to occupy the greater part of the long leg, is introduced into the absorption apparatus, and the connections throughout are tested to prove the absence

of leaks. When the outlet cock of the aspirator is opened, the escape of the contained water creates a partial vacuum, which is relieved by suction of air from the soil and through the whole apparatus. As the air emerges from the inlet tube of the absorption apparatus, it passes upward in the form of bubbles through the reagent, to which it gives up its content of CO_2. The reason for preferring the bulbed tube is that each bubble of air in its passage from one bulb to the next above is necessarily brought into more intimate and prolonged contact with the reagent than is the case when the plain bent tube is employed, for

FIG. 23.



Apparatus for determination of CO_2 in soil air.

here the air bubbles pass quickly along the upper inner surface of the tube, and are not so exposed to the reagent as to lose all the contained CO_2. For this reason, it is necessary to draw the air through a second, and, perhaps, a series of such tubes, but one bulbed tube as pictured above is sufficient.

The water from the aspirator is measured carefully, and its amount indicates the volume of air that has been sucked up out of the soil to take its place. When the desired amount has been acted upon, the stopcock of the aspirator is closed, and the reagent in the absorption

tube is transferred quickly to a glass-stoppered bottle of suitable size. From this point, the determination is the same as described in the chapter on Air.

Bacteriological Examination of Soil.

The bacteriological examination of the soil requires necessarily an intimate acquaintance with bacteriological technique, a subject beyond the scope of this work. It may be stated briefly that many of the organisms that inhabit the soil may be isolated by adding small portions of the sifted sample to liquefied gelatin and then plating, or by sprinkling over the surface of a nutrient medium, or by shaking with distilled water and transferring thence to the proper media.

The many anaërobic forms require, of course, the special treatment of their class, and some of them may be grown on ordinary culture media; but many of the saprophytes, notably the nitrifying organisms, cannot be isolated by the ordinary methods. For the details involved in the separation and identification of the numerous varieties of soil organisms, the reader is referred to the standard works on bacteriology.

CHAPTER IV.

WATER.

ABSOLUTELY pure water, that is, the substance composed wholly of hydrogen and oxygen, and represented by the symbol H_2O, is never found in nature, and is never seen, except in small amounts as a laboratory curiosity. In the broad sense, however, the word *pure* as applied to water conveys the idea of freedom from harmful ingredients and of wholesomeness and suitability for drinking and for the preparation of food. In nature, all water contains more or less of gaseous and solid substances in solution and suspension, and so long as these are not present in such amounts as to affect the quality injuriously, and so long as they are not intrinsically dangerous to health, the adjective is commonly held to be appropriate. But in the sense that purity involves the limitation of the amount of contained substances of a harmless nature, it becomes a difficult question where to draw the line where water ceases to be pure, and what term to apply as an antonym. In the sense that it involves complete absence of matters intrinsically dangerous, the line can be sharply drawn, and water which fails to satisfy the requirements of the term may be designated indifferently as impure, polluted, or contaminated.

In the classic reports of the State Board of Health of Massachusetts on public water supplies, waters are classed as "normal" or "polluted" according as they are or are not free from direct or indirect pollution by the waste products of human life and industry. Under this classification it follows, naturally, that normal waters must vary very widely in appearance, composition, and general character, and that a normal water is not necessarily suitable for drinking, although incapable of causing specific disease. The nature and amount of the dissolved matters cannot but have considerable influence in modifying the properties and effects of a water.

Waters may be classified according to source as follows:

1. Rain and snow.
2. Surface-water (rivers, ponds, basins, etc.).
3. Ground-water (also known as subsoil-water).
4. Artesian or deep well-water.

RAIN.

Rain is the original source of all natural waters of whatever class. It results from condensation of the aqueous vapor of the atmosphere, and in its descent to the earth it takes up gaseous and suspended matters from the atmosphere, which to that extent becomes thereby puri-

fied. In the open country, after the air has been washed for a while, the collected rain is very clean, and is, in fact, the purest form of natural water. If its fall is accompanied by wind from dusty localities, it cannot be obtained in so clean a condition within so short a time, on account of the greater amount of suspended matters to be washed down. Near the sea, it contains more or less salt; and in cities and large towns, it may have a slightly acid reaction.

In its passage downward through the atmosphere, rain absorbs considerable air, or, more properly, constituents of air; that is, oxygen, nitrogen, carbon dioxide, and ammonia compounds. Since each gas has its own coefficient of solubility in water, and as air is a mixture and not a chemical union of gases, it follows that water will absorb the constituents of air separately and according to their respective solubilities. So it happens that the absorbed air has a very different composition from that of atmospheric air, being much richer in oxygen and poorer in nitrogen, its oxygen content being 35 instead of 21 per cent. On reaching the earth, some of the rain is evaporated, some sinks into the soil, and some runs over the surface to streams or other bodies of water. The amount that sinks into the soil depends upon the permeability of the latter to water. Thus, a sandy or gravelly soil will take up more of the rainfall than a close-grained clay. The amount which is returned to the atmosphere by evaporation is surprisingly large. It has been reckoned by Dalton that in the whole of England and Wales, about 50 per cent. of the total annual rainfall is lost by evaporation. In the watershed of the Rhine, the loss is reckoned at 50 per cent.; in that of the Rhone, at 42; of the Seine, at 67, and of the Garonne, at 35.

SURFACE-WATERS.

Surface-waters are collections of water running along or stored upon the earth's surface in contact with the atmosphere. Under this head are included rivers and smaller streams, ponds, lakes, and impounding basins. They vary according to the different characters of the areas which they have drained or traversed, or in which they are stored. Thus, a water that has flowed over a rocky soil is more likely to be free from organic impurity than one that has flowed over loamy soil or has stood in swamps; and one that has flowed through sandstone bottoms is more likely to contain mineral impurities than one that has flowed over the virgin soil of a forest.

Surface-water means something more than the rain of the district plus the impurities of whatever character, organic and mineral, which it has collected. Rivers and lakes, for example, are made up of rain that has run over the surface of the ground, dissolving in its course small amounts of easily soluble matters, and of water that has come up from the soil below through springs, or that has trickled in from the upper layers of the soil; and these latter contribute matters which may be of very widely different character from those obtainable along the

surface, according to the geological character of the soil strata that have been acted upon.

A river may take its origin in a spring, and consist for some time of ground-water alone, but usually it is not long before it receives accessions of surface-water and soon acquires the characteristics of the latter. Again, some lakes and ponds are fed almost wholly by springs at their bottoms and sides; but even so, their waters soon change in character and acquire the various forms of aquatic life.

Surface-waters may contain much or little or no organic matter, according to circumstances. They may be colored or colorless; they may be rich or poor in mineral substances. Those which come largely from the ground will naturally possess largely the characteristics of ground-water, and those free from accessions from this source will approximate more nearly the character of rain. The quality of surface-waters is influenced by the seasons, by drought and rainfall, by vegetation, by rate of movement, and by other conditions.

GROUND-WATERS.

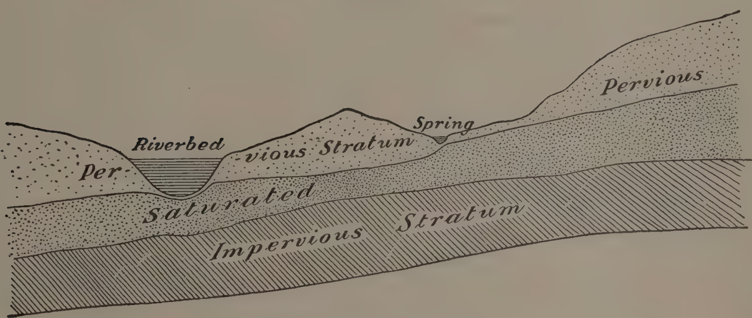
Ground-water is that which penetrates the soil, sinks to various depths, according to the nature of the soil, and accumulates on some more or less impervious stratum. It is not exposed to light and the atmosphere, like surface-water. It varies widely in character according to the nature of the soil over which it has once flowed and through which it has percolated. It enters with more or less air and CO_2 in solution, and comes in contact with the soil air in the interstices, which is much richer than atmospheric air in this gas. With the assistance of the CO_2 which it has brought, and that which it farther acquires in the interstices, it dissolves various mineral constituents of the soil. That which penetrates very deeply has its solvent power increased by increased temperature and pressure. As it enters the soil, it brings with it whatever organic matters it may have dissolved out of the surface layers, and in its descent it may lose them entirely through the action of the saprophytic bacteria of the soil, or it may acquire still more if the soil be polluted and so permeable as to permit rapid passage downward. It passes slowly or rapidly through the interstices until it reaches an impermeable stratum, over which it accumulates, filling the interstices completely. The soil at this point is said to be saturated, and the upper limit of saturation is known as the ground-water level, or water table. Between this and the surface, the water is in contact with the air of the interstices, and is known as capillary moisture. The water table is by no means necessarily horizontal, but follows in a general way the contour of the surface of the soil, and often it is much more irregular, and, by reason of local geological conditions, even quite different from what the surface formation would indicate. Thus, at one point in a level stretch of country, the table may be quite near the surface, and at another, a short distance

away, it may be situated much more deeply, owing to abrupt changes of level of the impermeable stratum.

Irregularity of the surface of the water table is due largely also to the rainfall, which, coming at frequent intervals, falls upon surfaces of differing permeability, so that while one part is still draining its water downward, another has completed the process and is ready for more. When drought occurs, however, the level becomes more and more uniform until it may become quite horizontal. With return of rainfall, the level rises, and irregularity of the surface of the water table is again produced. The level at any point is influenced also by the amount of water withdrawn from the soil by the demands made upon wells. When the amount of percolation is exceeded by the amount of withdrawal, the level falls; when the conditions are reversed, the level rises.

The water table in its irregular course touches the surface of the ground here and there, and gives rise to springs which may flow the

FIG. 24.



Outcropping of water table.

year round regardless of drought, or may dry up completely with fall of the level. Similarly, all permanent ponds are outcroppings of the water table, and the beds of rivers as well, but the level of the table in the near vicinity is almost invariably higher than the surface of these bodies. Sometimes, however, the water level is so near the surface that, without emerging in the form of springs, it extends in a broad sheet just at or below it and causes marshy conditions. In Fig. 24 the manner in which the water table crops out in springs and feeds lakes and other bodies of water is shown.

By some, the water table is spoken of as an underground river, a term which is very misleading, in that it suggests a body of water rather than a condition of saturation of the soil. There are, to be sure, in some localities, especially in limestone districts, bodies of water flowing between impermeable strata, and instances are known of disappearance of streams into fissures of rocks and emergence at a distance elsewhere, but these streams are not a part of the water table as generally understood and may not properly be classed as ground-water.

In most cases, and except where the water lies in deep depressions

or pockets with no side outlets, the ground-water is in constant lateral motion in the direction of the outfall, and this is commonly the nearest large body of water, either a lake, or a river, or the sea. In its onward course over an irregular impervious stratum, the movement is at times inclined upward and at times downward, but ever in the same general direction laterally.

The rate of movement is determined by a number of influences, among which the most effective are the degree of permeability, the inclination, and the barometric pressure. The degree of permeability, dependent upon the coarseness of the soil particles, is of very great importance, the more rapid flow occurring through the soils of coarser texture. The inclination, or, in other words, the influence of contour in promoting or preventing the assistance of gravity, has a very decided effect.

The barometric pressure affects the rate of movement through its effects on the air in the interstices above the water level. While this air is itself in constant movement, it cannot move quickly because of the great amount of friction created. Lessened pressure above the ground causes the soil air to expand, and as this occurs, the tendency is along the lines of least resistance, namely, upward and, under certain conditions, laterally, so that the water in the interstices is assisted in its flow. But the influence of diminished barometric pressure is felt almost at once at the outfalls, because of lessened back pressure on the water. This influence may be measured by noting the fluctuations in the water levels in wells which rise as the barometer falls, and fall as it rises. Thus, resistance is removed at the outfall, and coincidently the water is being pushed along by the expansive force of the air in the interstices. With increased barometric pressure, these conditions are reversed and the flow becomes less rapid.

The rate of movement being so dependent upon local conditions, it follows that it varies widely in different soils. In some places it is so slow as to be almost unmeasurable; in others it is extremely rapid; and even within a restricted area, it may be exceedingly variable at different points. At Budapest, for example, Fodor[1] determined the rate of movement at five different points to be 95, 125, 199, 209, and 210 feet daily. The average of these figures, 167.6, represents unusually rapid flow. At Munich, the daily rate of flow toward the Isar has been calculated by Pettenkofer as a trifle more than 15 feet.

Physical and Chemical Characteristics of Water.

At the standard barometric pressure, 760 mm. or 29.922 inches, water boils at 100° C. or 212° F. With lower pressures, it boils at correspondingly lower temperatures; on very high land, for example, it boils at such low temperatures that meat and vegetables cannot be thoroughly cooked in it. Evaporation occurs at all temperatures, even below the freezing-point.

[1] Boden und Wasser. Brunswick, 1882.

Water has its maximum density at 4° C., above and below which point it expands. At 0° C. it freezes, and in doing so, it expands to the extent of about 9 per cent. of its volume, and thus acquires a specific gravity less than that of unfrozen water, in which, therefore, it floats. As the surface freezes, it gives out heat to the layer immediately beneath and thereby causes a retardation of the process. As this layer becomes cooled, the ice formation continues, and thus the growth in thickness of the ice cover proceeds downward. Its specific heat is high, and is taken as the standard of comparison. As a conductor of heat it stands very low.

Water is the most universal solvent known, there being but few substances which are not acted upon by it to some extent. It takes up all known gases, and its solvent power for them is greater according as the temperature is depressed and the pressure increased. In the case of substances other than gases, with few exceptions its solvent power is increased with increased temperature.

Appearance.—Pure water is clear, and, in proportion as it contains dissolved air and carbon dioxide, is bright and sparkling. Brilliancy of appearance is, however, by no means conclusive evidence of purity, some extensively contaminated waters showing remarkable brightness. Turbidity of water is due to organic and mineral matters in suspension; the organic matters may be ordinary dead vegetable and animal substances or microscopic living plants and animals.

Some public supplies derived from rivers are distinctly muddy in appearance. The slight degrees of turbidity designated as *milkiness* and *opalescence* are due commonly to very minute clay particles, which may remain in suspension for a long time, even when the vessel containing the water is allowed to stand undisturbed. Sewage matters also may give these same appearances. Turbidity due to clay may be removed readily by the addition of various substances, as lime, alum, and sulphuric acid, which cause the particles to agglutinate and settle out. Water which is apparently clear when viewed in an ordinary glass vessel may be seen to have decided turbidity when viewed through a depth of a foot or two against a pure white surface.

Some ground-waters which are quite clear when drawn may acquire a turbid appearance on standing, due to the presence of compounds of iron which undergo changes in composition and become precipitated. In such cases, the turbidity is accompanied by the development of color, which, however, disappears on the completion of the process of oxidation of the iron compounds and their separation by sedimentation.

Color.—Water may have color or not, according to circumstances. Surface-waters may derive it from contact with grasses, leaves, woody matters in general, and peat, the degree of color being dependent upon the length of time of contact and upon the character of the substances. Different kinds of leaves, for example, impart different shades and kinds of color, but not always to the extent that their appearance would indicate. The dark-colored dried leaves of the oak, for instance, might be expected to yield a much darker infusion than the much

lighter colored leaves of the maple, but such is not the case, as may be proved readily by experiment; and those of the butternut give a color that is surprisingly light in comparison. Long contact with swamp vegetation causes a deep reddish-brown color, which is often very stable on long keeping. Not all surface-waters, however, are exposed to color-imparting substances, and waters of this class may be free from color.

Ground-waters of good quality are ordinarily colorless or appear to have, when viewed through considerable depths against a white surface, a faint bluish or greenish-blue tinge. Sometimes they contain iron and organic matter in combination, and have in consequence a brownish tint, which, by reason of very slow oxidation, may persist for a long time. Color derived otherwise than from contact with vegetable matter is accompanied usually by more or less turbidity. Absence of color is not a sign of purity, for polluted waters may be quite free from it; nor is its presence an indication of unfitness for domestic use.

Reaction.—The dissolved carbon dioxide in water tends to give it a slightly acid reaction, but most potable waters are very faintly alkaline to delicate indicators, owing to minute amounts of alkaline carbonates. Rain-waters, especially in the vicinity of cities and large towns, are generally slightly acid on account of impurities of the atmosphere, arising from combustion. Peaty waters also are slightly acid on account of organic acids produced by the action of the peculiar bacteria existing in peat. River-waters in mining districts often contain considerable amounts of free mineral acids.

Odor.—Pure water has no odor, but good surface-waters containing coloring matters have more or less odor, which is especially marked on heating. It is generally suggestive of vegetable matter, and may be characterized variously as grassy, peaty, etc., according to the impression produced. Such odors may persist even on long boiling, while those due to dissolved gases will disappear quickly on heating. Many otherwise good surface-waters are particularly prone to the development of disagreeable odors attributable to minute living organisms.

The subject has been studied very extensively by Mr. Gary N. Calkins,[1] who states that odors in drinking-waters "may be produced by the putrefactive decomposition of the body plasm through the agency of bacteria, and by the excretion of certain products of growth, or by the liberation of products by the physical disintegration of the body or breaking down of the enclosing cell walls. These three causes give rises to three classes of odors, as follows: (1) odors of chemical or putrefactive decomposition, (2) odors of growth, and (3) odors of physical disintegration."

The group of plants popularly known as "blue-green algæ" (*Schizophyceæ*) is a very common cause of the well-known "pig-pen" and "grassy" odors so frequently observed in shallow, stagnant, and relatively warm waters. Certain of the *Diatomaceæ* frequently cause serious trouble by imparting aromatic (geranium) and fishy odors

[1] Report of the State Board of Health of Massachusetts for 1892, p. 355.

and disagreeable taste. Of these, the most prominent is *Asterionella formosa*, found very commonly in large ponds and reservoirs of surface-water, and growing with especial luxuriance in open reservoirs of ground-water. According to Whipple and Jackson,[1] 3000 asterionella per cc. of water may, under favorable conditions, impart an odor easily recognized by the consumer. Several species of *Uroglena*, commonly, but according to G. T. Moore,[2] perhaps incorrectly, classed with the *Infusoria*, cause much trouble by the liberation, during disintegration, of oil globules which impart fishy, oily odors and tastes. These oil globules are yielded by many other varieties of water organisms.

While sewage matters impart mouldy or musty odors to water, it should not be inferred that these odors are of themselves indicative of sewage pollution, for good surface-waters sometimes acquire them on standing.

Sometimes it will be noticed that water on long boiling not only continues to evolve a vegetable odor, but gives it off in greater intensity. This is true particularly of waters rich in algæ. If they are first filtered, the odor will not be given off on boiling. But other waters may continue to evolve odors even after filtration. Peaty waters, for instance, often persist in yielding odor on long boiling, and this is not affected in any way by filtration. Waters containing products of physical disintegration and various other substances also are not influenced by filtration.

Odors which disappear on boiling may develop again after a time if their cause is not removed; if, however, the matters from which they are derived are no longer present, the odor will not return. Some most troublesome odors are known to be the results of decay. The public supply of Boston was, in 1878, seriously affected in this way, and gave off an odor which was likened to that of cucumbers. This was investigated by Professor Ira Remsen, who found the cause to be decomposition of a fresh-water sponge.

Water sometimes contains sulphuretted hydrogen from reduction of sulphates by bacterial action, and sometimes mixtures of products of organic decomposition which suggest that gas. Very marked and most offensive odors are due often to the presence of dead animals, such as toads and mice in wells, and, when they arise, the remedy is obvious. Some wells become stagnant at the bottom, and if organic matter is present, it may cause foul odor, suggestive of dead animals, by putrefaction in the absence of a sufficient supply of dissolved oxygen. Stagnation may be prevented by connecting the pump nearer the bottom, or by filling up the unnecessary space with clean gravel and sand.

Odors in water are not necessarily indicative of danger to health, but distinctly unpleasant ones are quite sufficient as a disqualification, on account of the repugnance which their use for drinking and other domestic purposes would cause. On the other hand, as in the case of

[1] Journal of the New England Water-Works Association, September, 1899.
[2] American Journal of Pharmacy, January, 1900.

color, absence is not indicative of purity, for dangerous waters may be inodorous.

Taste.—Pure water has no distinct taste, and, whatever the impression made, it is due to dissolved gases. That this is so, is most evident when one compares the taste of a well-aërated water, before and after heating to the boiling-point with subsequent cooling. Saline constituents impart no distinct taste unless they are present in quite large amounts, as in waters of a high degree of permanent hardness. The only substance which imparts taste when it is present in very small quantities is iron. Dissolved organic matters cause no taste, unless present in considerable amount and, as a rule, accompanied by odor.

Water containing very little coloring matter is often said to taste distinctly, but it should be remarked that the senses of taste and smell are often influenced unconsciously by the sense of sight, and colored water supposed to have both odor and taste may, if drunk in the dark, give no impression of either.

Badly tasting water, whether dangerous or not, is objectionable on the same grounds as mentioned under odor. Not only is absence of bad taste no evidence of purity, but it is well known that waters containing the products of oxidation of sewage are often remarkable for unusual palatability.

Substances Found Normally in Water.

These include:

1. Gases in solution.
2. Organic matters in solution and in suspension.
3. Mineral matters in solution and in suspension.

1. **Gases.**—First in importance is air. Strictly speaking, water contains no air as such, but only the constituents of air, for the oxygen and nitrogen, dissolved by water, are not present in the same proportion in which they exist in the atmosphere. In salt water, the variations in their proportions are less wide. We shall, however, consider the two gases as air. The dissolved oxygen is the important element. One hundred volumes of water at 15° C. will dissolve nearly 3 volumes of oxygen (2.99), and at 20°, 2.80 volumes, and it is not altogether removed by boiling.

The amount of oxygen in solution is fairly constant in waters of uniform composition freely exposed to the atmosphere, but when they receive additions of sewage and other oxidizable matters they begin to lose it. River-waters may thus show notable differences in the amount of dissolved oxygen present in samples taken above, within, and below towns situated on their banks. The Thames and the Seine, for instance, show this in a remarkable degree. The progressive diminution is due to the constant access of organic matter, which undergoes oxidation at the expense of the dissolved oxygen. When a river-water is deprived of its dissolved oxygen in this manner, or by reason of chemical changes due to the inflow of sewage from manufacturing

establishments, containing compounds—ferrous, for instance—having a strong affinity for oxygen, fish life cannot be supported. Absence of fish in polluted streams is due much more to diminution of dissolved oxygen than to the poisonous effects of organic sewage.

Aëration of water is influenced very largely by the dust which falls into it, for each particle carries with it more or less adherent air, as may readily be seen when one drops small particles into water and observes their descent. Aëration of water proceeds to great depths, as is shown by chemical analysis of samples of water obtained by deep sounding, and also by the fact that great numbers of organisms which require oxygen for their respiration are found far beneath the surface; but water at 40 and 50 feet below the surface may contain no oxygen. Water from deep wells is very commonly free from dissolved oxygen, because of abstraction by compounds of iron or manganese, organic matters, and other substances.

The presence of considerable dissolved oxygen in water leads to beneficial changes in the organic matter present. Diminished oxygen permits the development of low forms of vegetable life, which frequently give rise to unpleasant tastes and odors. Their growth is inhibited by a large degree of aëration, and their disagreeable effects are thereby prevented.

Carbon Dioxide.—The carbon dioxide contained in water is derived largely from the atmosphere, and in great part from the soil, where it is present in abundance. Its amount in any water depends upon a number of circumstances: upon the amount carried in by rain and dust, the character of the soil, and the extent of oxidation of organic matter occurring in the interstices. It is greatest in amount at great depths, and it may constitute almost the entire content of dissolved gases. It has been calculated that the ocean contains about ten times as much as the entire atmosphere.

2. **Organic Matter.**—The organic matters in water are of both animal and vegetable origin, and consist of organisms, products of organic life, and results of disintegration and decomposition. The animal matters include dead and living organisms and dissolved and suspended products of animal life and decay, such as albuminous substances, urea, and tissues. In the tropics and subtropics, ova and young of various parasites are common. Ordinarily our interest in organic matter from animal sources is confined to the products of human life as represented by sewage, which may contain the exciting causes of specific diseases (see Bacteria in Water, page 332). Vegetable organic matter exists as living and dead organisms and tissues in suspension, soluble and suspended substances given off during life, and soluble matters extracted by the water after death.

The vegetable organisms are represented by very numerous species of microscopic plants, which act beneficially by absorbing the products of organic decomposition for their growth, but which may, on the other hand, under favorable conditions, become the source of much trouble by over-abundant growth, disintegration, and decay. They may prop-

erly be regarded as normal constituents of surface-waters, for they are always present in such, and, moreover, they develop quickly in stored ground-water exposed to light and air. When they die, most species appear to decay rather slowly, and the products of their decomposition are absorbed by new growths; but when present in great abundance, the progress of decay may exceed that of growth, and then their products may accumulate and cause foulness.

There is one form of microscopic organisms, belonging to the class of fungi, which merits special mention: *Crenothrix Kühniana.* This is a filamentous plant with cells no larger than the ordinary bacteria. It grows chiefly in ground-waters which contain organic matter and iron, the latter of which ingredients it fixes in the form of ferric oxide in the gelatinous sheath of its filaments, which thereby become yellow, yellow brown, or brown in color. It causes great annoyance by the rapidity with which it grows in water-pipes, the lumen of which is not infrequently completely occluded. This may occur more readily where the surface presents roughness and imperfections, to which the growths may attach themselves. When the filaments are broken off and become disseminated through the water, the latter is rendered unfit for laundry use on account of the iron-rust. Sometimes, it gives rise to disagreeable odors and an inky taste. It may be very troublesome within the tubes of driven wells, or in the reservoirs, as well as in the distributing pipes. Sometimes, it may be seen in large aggregated masses floating about on the surface of stored water. By its extensive growth in pipes, it may seriously affect a whole public supply.

The presence of living forms, either vegetable or animal, indicates that the water contains at least whatever food materials are necessary for their existence, but not necessarily that these are in excess. Algæ, for instance, require mineralized nitrogenous matter (nitrates), and other substances; fungi suggest the presence of carbohydrates, proteids, and mineral substances common to domestic sewage; infusoria suggest organic decomposition. Dissolved vegetable matters ordinarily amount to but little in weight. Even in some very brown waters, whose appearance would suggest large amounts, they may be present to the extent of not more than 1 or 2 parts in 100,000.

The organic matters, both animal and vegetable, which are of interest to the sanitarian, consist chiefly of carbon, hydrogen, oxygen, and nitrogen, with, in many cases, small amounts of phosphorus and sulphur. In the process of decomposition, which owes its inception, progress, and completion to bacterial activity, the carbon is combined with oxygen to form carbon dioxide, and the hydrogen unites in part with nitrogen to form ammonia, the presence of which in water indicates that the process of decomposition is under way. In its turn, as will be shown later, the ammonia is converted eventually to nitric acid, which unites with bases to form nitrates.

Ammonia.—From the standpoint of sanitary significance, ammonia in water is of prime importance. Only under very unusual conditions does it exist in the form of hydrate, but usually as chloride or car-

bonate. We speak of it commonly as *free ammonia*, for, on boiling the water, these salts are decomposed and the ammonia is expelled in the steam. Among the direct sources of ammonia in water is rain, which brings it down out of the atmosphere in varying amounts according to location. Rain always contains it, but more is present in that of thickly populated districts than in the open country. In one instance, reported by Drown,[1] it was found to the large extent of 0.0564 in 100,000. Its presence, however, in surface- and ground-waters is due for the most part to decomposition of nitrogenous organic matter. It is not abundant in ordinary unpolluted waters, but is present often to a very considerable extent in that of deep driven wells. Here its origin is not always clear; in some cases it is supposed to be referable to coal deposits, in others to reduction of accumulated nitrates.

Under ordinary conditions in surface-waters, ammonia, after conversion to nitrates, is absorbed very quickly by growing vegetation, and the more active the conversion and the growth, the greater the appropriation. For this reason, water from the same source will often show less on analysis in summer than in winter. But activity of vegetation is not responsible alone for this difference in amount, for in the case of large bodies of water, as lakes and ponds, the rate of movement of the water has great influence. During the warmer months, when the upper layers are warmer and consequently lighter than the lower, the latter become necessarily stagnant and stratified. The ammonia which accumulates in these lower strata does not, therefore, come to the surface until cold weather approaches. Then the upper layers become more dense and tend toward the bottom, causing a displacement of the lower layers toward the surface and general uniform mixing of the entire volume of water. Another element in the stirring up of the water of ponds and lakes is the action of wind, which, however, does not extend beyond twenty feet. Still another influence to be considered is that of springs at the bottom and sides, which tend to keep the water in motion. In the case of flowing rivers, the water is of comparatively uniform composition at all depths.

Ammonia is very characteristic of sewage pollution, the oxidation of which yields it in abundance under conditions which do not permit it to be rapidly oxidized to nitric acid.

Ammonia as it occurs in drinking-water is of itself incapable of producing harmful effects. Its amount, however, is of greater or lesser significance according to circumstances: that from clean and properly stored rain-water is of far less significance than that from other waters. In the one, it may be considerable in amount and mean but little; in others, it is usually evidence of decomposition of organic matter. Its amount in good water is not large, and on account of oxidation and absorption by vegetable growth it does not accumulate. And even in sewage-polluted waters, when vegetation is active, oxidation and

[1] Massachusetts State Board of Health: Report on Water Supply and Sewerage. Boston, 1890. Part 1, p. 562.

absorption may so diminish its amount that, taken alone, it might lead to false conclusions as to the character of the water.

Albuminoid Ammonia.—The so-called albuminoid ammonia is ammonia which is produced in the process of analysis of water by the action of alkaline permanganate of potassium on nitrogenous organic matter hitherto undecomposed. The result of the action is a splitting up of the organic matter and the conversion of the nitrogen to ammonia, which, as is the case with "free" ammonia, passes out of the water in the steam. This matter may be of either animal or vegetable origin, and its character is of far greater importance than the amount of the yield. Thus, a water grossly polluted by sewage may yield less than another quite free from such contamination, but rich in dissolved vegetable matter of no great sanitary importance.

Animal organic matter is decomposed much more rapidly than vegetable matter, some kinds of which are remarkably permanent, such, for instance, as the substances which impart the brown color to the waters of swamps. Animal matter is richer in nitrogen than vegetable matter, and consequently a stated amount of albuminoid ammonia represents decomposition of a larger amount of the latter than of the former. In other words, a small amount of animal matter will yield as much albuminoid ammonia as a large amount of vegetable matter.

Inasmuch as animal matters are of far greater significance than vegetable matters, it must be clear that the amount of albuminoid ammonia is of less importance than its origin. And since, in the analysis of water, the ammonias themselves give no indication of their origin, their significance can be measured only with the aid of estimations of other substances; and often, also, a knowledge of the source of the water and its surroundings will be required.

Nitrites and Nitrates.—The ammonia formed in the first stage of decomposition and that washed out of the air by rain are oxidized eventually to nitrates under the influence of the so-called nitrifying bacteria, and this stage marks the completion of the process. The nitric acid formed, coming in contact with earthy and alkaline carbonates, attacks them and unites with the bases to form nitrates and, in so doing, liberates carbon dioxide. The nitrifying process occurs not alone in the body of the water itself, but to a much greater extent in the interstices of the soil, so that a water rich in all manner of organic substances undergoes, under favorable conditions, this purifying process in the fullest degree when it enters the soil at the surface and percolates slowly downward. Before the stage of complete nitrification is reached, there is an intermediate stage, that of nitrous acid and nitrites, but it is probable that the time during which a given amount of nitrogen on its way to mineralization remains in the nitrous form is extremely short; in fact, the step from ammonia to nitric acid is practically instantaneous. Nitrates are seldom absent in either surface- or ground-waters, and may be present, especially in the latter, in quite large amount (as much as 6 or 7 or more parts in 100,000); while, on the other hand, nitrites are

not ordinarily present in unpolluted waters, and as little as $\frac{1}{1000}$ part in 100,000 of any water is looked upon as "high."

It is a fact that nitrates are reduced very readily to nitrites, and farther back to ammonia, and even to nitrogen gas itself, by a variety of organisms which act in the absence of oxygen. These are known as the denitrifying bacteria, and while these species are doubtless very numerous, only a limited number have been isolated and identified. Their action is inhibited by oxygen, as has been proved by Stutzer and Maul,[1] who found that the process of denitrification ceases in cultures through which a stream of oxygen is passed. This was confirmed by Weissenberg, who observed, further, that when the bacteria were cultivated in small volumes of nitrate bouillon in flasks of such shape that the surface of the liquid was very great in comparison to its depth, and exposed to the air, they did not act.

These bacteria are common in sewage in which the conditions for their growth and activity—absence of dissolved oxygen, for instance—are present. Grimbert[2] has shown that *B. typhosus* and *B. coli communis* reduce nitrates and amido principles in culture media. The production of gas appears to be a result of the secondary reaction on the amido compounds by the nitrous acid formed through bacterial action.

Small amounts of nitrites in water may be derived from the air by absorption or by the cleansing action of rain, and may be due to contact of metallic surfaces, brickwork, and new masonry with the nitrates in solution; but they are almost never present in what are called large amounts (one part in a hundred million) except as an indication of sewage pollution.

The disproportion between the amounts of nitrites and nitrates in water may also, perhaps, be explained as follows: The nitrates are the final stage of complete oxidation; they do not go on to a higher form, but, being permanent in character, accumulate in the water, unless withdrawn by vegetable life or reduced. The nitrites cannot accumulate as such, but are converted to the higher form. Thus, the lower form is constantly passing into the higher, and is stored as such.

Nitrates vary considerably in amount, owing to various causes. They are almost always present in both surface- and ground-waters, unless there is some process at work causing a reduction to nitrites. In unpolluted surface-waters they are usually low in amount, but such waters generally contain more nitrogen in this form than as ammonia. They do not accumulate greatly in such waters during the warmer months, for they are absorbed largely by growing vegetation. Hence they are more abundant in winter. In the warmer months they may be absorbed almost wholly by growing algæ.

Ground-waters contain little or much, according to circumstances; in virgin and thinly settled districts the amount is small; in others, it is usually fairly high. In the former, it is mainly from the ammonia

[1] Centralblatt für Bakteriologie, Abth. II., Bd. 2, 1896, p. 473.
[2] Annales de l'Institut Pasteur, Jan., 1899.

of the rain and that formed in the decay of the organic matters naturally in the soil; in the latter, it is due largely and mainly to the ammonia of domestic sewage.

Ground-waters rich in nitrates, when exposed to light and air, generally become more or less rich in vegetable growth, and poorer in nitrates.

Like ammonia, nitrates in water are not of themselves in any way harmful in the amounts found. They simply represent what was once organic nitrogen, but now completely mineralized. Nor is their presence any indication of the nature of the original organic matter, whether animal or vegetable, and this can be inferred only when other constituents are considered. When present in considerable or very high amounts, they indicate a corresponding degree of *past* pollution, perhaps nearby existing pollution, and the possibility of future danger from its recurrence. Therefore, high nitrates should sometimes be looked upon with suspicion.

And, furthermore, it should be borne in mind that the evidence of extensive mineralization does not preclude the existence of present processes and the presence of active pathogenic micro-organisms, for organic matter may be oxidized rapidly in the presence of living pathogenic germs. Sometimes, very large amounts of nitrates are found in the waters of very deep wells, so large that they cannot be explained by the supposition of oxidized sewage. In these cases the cause is surmised to be fossil remains or natural nitrate deposits.

The presence of nitrites in water is of far greater importance than that of nitrates. It means that fermentative changes are in progress, and that oxidation is not being completed. When this condition obtains, nitrites may be very persistent. Sometimes, they mean a reduction of the nitrates, which takes place mainly under the influence of denitrifying organisms, quite likely to be present in large numbers in decomposing organic matter. Sometimes, neither nitrates nor nitrites are present in sewage-polluted water; in such cases, either they have not been formed or they have been completely reduced.

When nitrites are present at the expense of the nitrates by the action of metallic surfaces, lead and iron, for example, the metals themselves are present in at least detectable traces.

3. **Mineral Matters.**—**Chlorine** as **common salt** is a normal constituent of all waters. Rain-water takes it up from the air in small traces, particularly near the sea coast. In the specimen of rain referred to on page 327 as rich in ammonia, the chlorine content was 0.13 per 100,000, which is much in excess of that found in many inland waters. The amount of chlorine normally present in the water of a district depends on location and other conditions. It is influenced very greatly by proximity to the sea, the air above which contains necessarily more than that at a distance inland. It varies in amount in the same water with differences in the amount of rainfall and evaporation, and in the direction of the wind.

Chlorine increases directly with the population, and its amount is

influenced very greatly by a proper system of sewerage which carries the sewage matter, rich in common salt, beyond the limits of the drainage area. When its amount rises above the normal of a locality, it is indicative of sewage, though not necessarily of recent pollution. As we have seen, the organic matters become mineralized, and no longer exist in their original form; but no such change occurs in the chlorides, which remain fixed and unchanged, and they may be the only evidence remaining. Thus a water polluted by sewage may have its organic nitrogen converted to nitrates, and these in turn may be absorbed by vegetable growth; it may be clear, colorless, odorless, and palatable, free from pathogenic bacteria, and in every way suitable for drinking, but, nevertheless, the chlorine remains as a witness that pollution has occurred in the past.

According to Professor Drown, in a general way 4 families, or 20 persons, per square mile will add on an average 0.01 part of chlorine per 100,000 to the water of a district in seasons of average flow, and more in time of drought.

Other Mineral Matters.—The total amount of dissolved mineral matter in any drinking-water depends upon the character of the soil with which the water has been in contact, upon the length of time of exposure, and upon the amount of carbon dioxide held in solution. Not even the hardest and most insoluble rocks wholly escape the solvent power of water: no mineral is absolutely insoluble. Silicate of aluminum, which is least acted upon, is soluble to the extent of about 1 part in 200,000. Silicious rocks in general are attacked only very slightly, while limestones are dissolved with comparative ease, and yield considerable calcium and magnesium carbonates, especially if the water is rich in free carbon dioxide. Gypsum also is acted upon very freely.

Some waters contain very large amounts of mineral matter, derived from deeply situated natural deposits. The Carlsbad springs, for example, are said to bring annually to the surface enormous amounts of sodium chloride and calcium carbonate, besides 2,500 kilos of calcium fluoride, 600,000 of sodium carbonate, and 11,000,000 of sodium sulphate.

Besides the ordinary salts of the alkalies and alkaline earths, most natural waters contain at least very minute amounts of iron. Appreciable amounts of iron make water unsuitable for general domestic and technic purposes. It causes staining of clothes if used in the laundry, and headache, dyspepsia, and constipation if used habitually for drinking. It cannot be used for dyeing, and as little as 1 part in 1,000,000 makes it unsuitable for use in bleacheries. A quarter of a grain per gallon is sufficient to impart a distinct chalybeate taste.

The permissible total amount of dissolved mineral constituents cannot be stated, but 50 parts in 100,000 are generally held to be excessive.

Hardness.—Hardness is the capacity a water has for decomposing soap. It depends on the amount of salts of Mg and Ca in solution, and hence upon the character of the soil with which the water has been

in contact. Water from rocks which yield lime and magnesia will probably be hard, while that from those composed of alumina, silica, etc., will probably be soft. Some sandstones will yield soft and others hard water, according to the nature of the cement which binds the grains together. The elements causing hardness, particularly the calcium salts, have the property of making new combinations with the fatty acids of the soap, and preventing the formation of a lather until they have been satisfied: 1 grain of chalk, for instance, will use up 8 of ordinary soap before any effect can be produced; hence enormous waste of soap occurs from the use of hard water.

Hardness is divided into "temporary" and "permanent." The former is due to salts which are removable by boiling; the latter, to those which are not thereby affected.

Water containing considerable free CO_2 can take up and hold considerable carbonate of lime by means of this gas. Some claim that the carbonate is changed to bicarbonate, but this compound has never been isolated. If the gas be expelled by heating, the solvent power no longer remains, and the amount so held is precipitated, and then can exert no more influence in causing hardness. The chloride and sulphate of calcium are not affected by boiling. Magnesium carbonate is precipitated, but redissolves on cooling.

The difference between the original hardness and the hardness remaining after boiling is the "temporary" hardness. Permanent hardness is, then, due to those salts not affected by boiling, that is, to calcium sulphate and chloride, and magnesium salts; and if above 5 parts in 100,000, is commonly regarded as excessive and injurious. Calcium sulphate is not alone objectionable in drinking-water, but also in water used in boilers, since it is less soluble in hot than in cold water, and thus forms a "scale." Scale is of two kinds: that due to the temporary hardness, easily removed; and that from $CaSO_4$ which is hard, very adherent, and removed with difficulty. The latter is deposited the more freely, the higher the temperature of the water.

Boiler scale sometimes is due also to other causes. For instance, A. Reichard[1] has reported a case where serious difficulty was caused by the formation of a scale of silica and lime from a water which contained only 2.30 parts of lime and magnesia, but as much as 2.60 of silica. Boiler scale causes great loss of fuel, by interfering with the transmission of heat to the water. Hardness is not only undesirable in water used in the laundry and bath, but also in that used for cooking purposes, for it makes certain of the vegetables hard and indigestible.

Bacteria in Water.

The ordinary water bacteria are of the harmless and beneficent kinds, which, depending upon dead organic matter for sustenance, bring about its conversion into simple chemical substances. How many species of these saprophytic organisms exist in water cannot be said, but about

[1] Chemiker Zeitung, 1896, p. 65.

two hundred varieties have thus far been described. They may be present in small or in enormously large numbers without being necessarily of hygienic significance, although usually their existence in large numbers indicates the presence of an abundance of organic matter, and yet they may thrive and multiply enormously in water containing almost no organic food materials. Indeed, multiplication occurs more rapidly in pure than in polluted water, but diminution in number is also more rapid. In impure water, they multiply slowly, but their growth is persistent, and, under ordinary natural conditions, sudden marked diminution in number does not occur.

The ordinary water bacteria are found in much greater abundance in surface-waters than in those derived from the soil. Indeed, many observers, including Koch and Fraenkel, have maintained that waters from the unpolluted subsoil are practically sterile. This, however, has been shown by Sedgwick and Prescott[1] to be not the case. Using improved methods of investigation, and paying special attention to the nature of their culture media, these observers demonstrated conclusively that wholly unpolluted springs, wells, and tube wells may yield considerable numbers of bacteria and sometimes a greater abundance than is contained in some surface-waters. In their paper they state "that the plates are remarkable not only for the slow growth of the species present, but also for the absence of liquefying colonies, and, in many cases, for the abundance of chromogenic varieties. These facts are especially important as indicating the total absence of contamination by ordinary surface-water, and, as far as they go, they strengthen the confidence with which well-protected ground-waters may be regarded as sources of public water supplies." Their conclusions and results have been confirmed a number of times by other competent investigators elsewhere. Ground-waters, when brought to the surface and exposed to the air, soon become rich in the ordinary forms of bacteria, which find in them the conditions necessary for extraordinarily rapid multiplication.

Surface-waters vary very much in their bacterial content according as the conditions present at any one time favor or retard growth and accessions. Sunshine, influx of food material or of substances inimical to bacterial life, sedimentation, and growth of higher organisms act for or against increase. Suspended matters in their descent carry down with them the bacteria that have gathered upon them or have been entangled by contact. The diminution in their number by this means is more marked in still waters than in rivers with rapid motion. The growth of algæ and other water plants causes diminution by removal of the nutrient materials upon which the bacteria depend, and probably through some other influence not yet discovered. The increase in bacteria, sometimes noticed during the colder months, is explained by Frankland[2] by the fact that in winter much water runs in over the surface from manured fields.

[1] Report of the State Board of Health of Massachusetts for 1894, p 435.
[2] The Bacterial Purification of Water, London, 1897.

Besides those forms whose natural habitat is water, others are often present whose natural habitat is the bodies of man and animals, and which, in water, are, therefore, in an unnatural medium. These forms, which include the pathogenic varieties, probably do not increase in number in water, whether the latter be pure or extensively polluted. They live for a certain time, retaining their virulence in undiminished degree, and then tend to become modified in this respect and rapidly to disappear. The germs of cholera have been found in Seine water in an active state after seven days, and in ordinary drinking-waters as long as twenty days after addition. The typhoid fever organism will live for longer or shorter periods, according to circumstances; it has been found in very pure water after more than seven weeks, while in badly polluted water its life is very short. Sunshine and temperature appear to have very decided influence upon its vitality. The influence of sunshine is modified by the depth of the water in which the organism is suspended. Buchner[1] has shown that the rays of the sun will kill cultures of the typhoid bacillus at a depth of about five feet in four and a half hours, while at double that depth their effects are hardly perceptible. While it is true that this organism survives longer in cold than in warm weather, it cannot be said definitely that the reason lies in any inherent greater resistance to the influence of cold than to that of heat; and, indeed, it seems more probable that the explanation is to be found in the fact that in warm weather the conditions are more favorable to the growth of the common species of water bacteria which are believed to secrete substances which exert a toxic influence on pathogenic varieties and cause them to disappear. The belief that such toxins are secreted is strengthened by the researches of Frankland,[2] who shows that waters which do not favor bacterial multiplication are changed in this particular on being boiled. He found that, while anthrax spores were much diminished in number or actually destroyed in a short time in unsterilized water, their numbers were not reduced and their virulence remained unimpaired in sterile water after upward of seven months. These toxic substances are presumably not secreted by all forms of water bacteria, but only by certain species which may or may not be present in any given water, and it is regarded as most likely that they are not inimical to the same extent to all varieties of pathogenic bacteria, but that substances harmless to one kind may act fatally on another. In general, it may be stated that pathogenic bacteria which form spores retain their vitality and virulence longest in any kind of water.

Concerning the significance of *B. coli communis*, which is exceedingly common in drinking-water, there is much difference of opinion. Kruse,[3] in 1894, asserted that this organism is so ubiquitous that it cannot be regarded as characteristic of sewage, and in this position he has received the support of a number of other investigators, who have

[1] Centralblatt für Bakteriologie und Parasitenkunde, XI., p. 781

[2] Journal of State Medicine, January, 1894.

[3] Zeitschrift für Hygiene und Infectionskrankheiten XVII., p. 1.

succeeded in isolating the organism from all waters examined, although in many cases it was necessary to employ large volumes of the samples.

The committee of the Laboratory Section of the American Public Health Association, to which the question of the significance of *B. coli* in water supplies was referred, reported[1], in October, 1903, that, in spite of the fact that numerous investigators have found the organism where it could not directly be traced to sewage or fecal pollution, the colon test of water is a safe index of pollution; that their number rather than their mere presence should be used as a criterion of recent sewage pollution; that evidence of the presence of *B. coli* in a majority of 1 cc. samples should be required for a conclusion that a water is sewage polluted; and that the examination of large (100–1000 cc.) samples for *B. coli* should be discouraged (one of five members dissenting). On the question of the desirability of isolating streptococci as well as *B. coli*, to confirm suspicious evidence of pollution offered by *B. coli*, there was no agreement, but great diversity of opinion.

According to Clark and Gage,[2] of the Lawrence Experiment Station, whose conclusions are based on the results of examination of some 16,000 samples of water from all sources and of more than 2000 miscellaneous samples of shellfish, sea-water, ice, milk, dust, excrement, etc., the colon bacillus, occurring more numerously than all other bacteria in normal sewage, is the most valuable index of sewage. When a considerable number of samples from the same source are examined, 100 cc. samples frequently give more information as to quality than do single cubic centimeter samples. In filtered polluted water, bacterial tests are of greater value than chemical analysis; and disturbing factors in filtration, shown slightly or not at all by ordinary bacterial counts, are often shown strongly by *B. coli* tests.

WATER SUPPLIES.

Immediate sources of water supply comprise: 1. Stored rain. 2. Surface-waters, including rivers, lakes, and gathering basins. 3. Ground-waters, including wells, filter galleries, and springs.

1. STORED RAIN.

Where other water is not obtainable, and where the natural water is unfit for drinking or for washing and other domestic purposes, stored rain-water is used. If this is collected under proper precautions to prevent the presence of extraneous matters of undesirable character from the receiving area, and properly stored, it constitutes a most wholesome supply. But excepting where rainfall occurs with regularity and frequence, the uncertainty of supply, especially in periods of drought, acts as a great drawback. An inch of rainfall is equivalent to 5.61 U. S. gallons per square yard, or 27,152 gallons per acre, but

[1] Public Health Papers and Reports, XXIX, p. 356.
[2] Ibidem, p. 386.

only a small proportion of this falls upon surfaces (roofs, etc.) from which it may be collected.

The total collecting area of the roof of any building depends not upon the shape and style of the roof, but upon the amount of ground occupied by the building. Thus, a house 40 feet square will have practically 1,600 square feet of watershed, or, allowing for the projection of the eaves, somewhat more, and this whether the roof be flat, pitched, gambrel, mansard, or irregularly disposed. Upon such an area, 1 inch of rain will yield nearly a thousand (997) gallons. The mean annual rainfall of Massachusetts is 43.17 inches, and on this basis, a roof of this size would receive in a year over 43,000 gallons, which would allow for all the needs of the occupants, for drinking, cooking, bathing, laundry, and other purposes, nearly 120 gallons per diem. But under ordinary conditions of storage in cisterns, a very large amount of loss occurs through evaporation, and thus the daily allowance would fall somewhat below this figure.

In collecting rain from roofs, it is very necessary to insure cleanliness of the supply, by allowing the first flow to run to waste, thereby avoiding contamination by dirt, leaves, bird-droppings, soot, and other matters deposited upon the roof and collected in the gutters. A number of automatic devices are in use for the purpose of diverting the first washings away from the conductors. After this has been done, they change position, so that the subsequent fall is saved and stored.

Irregularity in precipitation is, as has been remarked above, a serious drawback to reliance upon rain as a sole supply. Partly owing to a general belief that great battles, in which large quantities of explosives are used, are commonly followed by heavy rain, numerous experiments have been tried toward breaking drought by discharging powerful explosives in the upper strata of the atmosphere, but without success. As a matter of fact, the idea of connection between battles and rainfall is by no means new, and has, indeed, come down from times antedating the use of gunpowder in warfare. Furthermore, investigation of government records has shown that the popular belief has no foundation in fact, and that great battles have been as often followed by periods of fair weather as by days of storm.

Rain-water requires no aëration, for in its descent it has absorbed considerable air; but melted snow and ice should be shaken with air or poured repeatedly from one vessel to another, in order that they may lose the flat taste so characteristic of unaërated water. Moreover, their use in the flat condition is believed to conduce to gastric derangement. Snow-water is usually more impure than rain, because the snowflakes, by reason of their larger surface, are more efficient in removing dust and dirt from the air.

Cisterns for storage of rain should be so constructed and arranged as to admit of easy inspection and cleansing. They should be kept covered, so as to exclude dirt and dust of all kinds, insects, mice, and other animals, and to shut off light as well, for the presence of light is an important aid to the development of lower plant forms. The

best materials for their construction are bricks, stone, cement, and slate. Cement makes a good lining if one is desired; mortar, however, is objectionable on account of the solvent power of water upon lime, which will cause progressive increase in hardness. Cisterns should be provided with overflow pipes discharging into the open air rather than into the house sewer, and their exits should be protected by wire netting against the entrance of leaves and small animals.

2. SURFACE-WATERS.

For public supplies, especially of large communities, surface-waters, as rivers, lakes, and collecting basins, are generally more available than ground-waters.

Large rivers and lakes are, unfortunately, very commonly subject to most extensive pollution by sewage of large communities and manufacturing establishments along their borders, and by the waste products discharged into them from sailing vessels and steamships. Many rivers are subject to progressive increase of pollution by reason of serving as the most convenient receptacle for the sewage of a succession of towns and cities located at intervals from the source to the mouth. Thus, one town takes its water from a point above and discharges its sewage at another place below; a second, farther down, takes the already contaminated water, and in its turn discharges its sewage at another convenient point, and so on for the rest of the course. On account of the dangers attending the use of such waters, some process of treatment is imperatively demanded to remove the objectionable elements. The different processes available for this work are considered elsewhere.

The public mind is being awakened gradually to the wrong practised upon one community by another by the discharge of untreated sewage into what is its only available water supply. In the case of cities located upon the shores of the Great Lakes and other large bodies of fresh water, it is commonly the case that the intake of the water supply is located at no very great distance from the outfall of the main sewers. Smaller rivers and lakes may be subject to the same influences, though in lesser degree; but, in general, it may be said that these are controlled more easily, especially when they lie wholly within the jurisdiction of a single law-making power.

Basins for the collection and storage of rainfall and surface-waters are constructed by throwing a dam across a valley or other convenient depression. Experience has taught, that, even though involving large expenditure, it is best to strip off the surface layers in order to get rid of all organic matter and vegetation, which, if left in place, may prove fruitful sources of trouble. The water which gathers in them has opportunity to rid itself of much of its suspended matters by sedimentation, and is more often used without further treatment than otherwise.

All surface-waters contain more or less active vegetation, and on that account should always be kept exposed to light and air, otherwise

the minute plants will die, and in their decomposition give rise to unpleasant odor, appearance, and taste. Storage reservoirs should have sufficient depth to prevent the water from becoming heated to an unpleasant degree during the warm months of summer. In shallow reservoirs, this is found to be a common occurrence.

All sources of surface-water for public supply should be carefully guarded against sewage contamination. It is often necessary to secure protection from pollution by taking great tracts of land and keeping them free from human habitations and industrial plants.

3. GROUND-WATERS.

Some large communities and many small ones where no suitable bodies of surface-water are available for public supplies, and the majority of thinly settled districts which do not admit of public waterworks, depend upon the ground-water as the source of supply. For public distribution, the water thus derived is stored in suitable reservoirs, which often must be covered, in order to exclude light. Ground-water is destitute of plant life, but is generally more or less rich in mineral constituents—nitrates, and lime salts, for example—which constitute appropriate plant food. If exposed to air and light, vegetable growth may start up and become very luxuriant, and give rise to unpleasant tastes and repulsive odors, while exclusion of light and air prevents the difficulty.

For individual domestic supply, storage is not ordinarily necessary, the water being obtained only as immediately needed or pumped periodically into small distributing tanks.

In general, unpolluted ground-water of not excessive hardness is preferable to surface-water, on account of the greater exposure of the latter to the many risks of pollution. But it should be borne in mind that all sources of supply, both surface- and ground-waters, may, under one condition or another, be subject to polluting influences, and that the conditions prevailing in one locality are likely to be quite different from those in another.

Ground-water is obtained from springs, or by sinking wells, or by constructing filter galleries.

Springs are merely local outcroppings of the water-table, and are very subject to variations in the volume of outflow. In time of drought, they sometimes cease their flow completely, because of fall in the level of the ground-water; and this may happen even in the case of those located at the foot of high hills or mountains. The popular mind endows springs with a remarkable and unvarying degree of purity, but they share with other waters the likelihood of becoming polluted. The possibility of contamination after and even at the point of issuance from the ground is too often overlooked.

Springs are common to some localities and rare in others of similar contour, their presence or absence being determined by conditions not of the surface, but of the geological formations below. In Figs. 25 and 26 are shown in profile two depressions having the same contour,

but with very different arrangement of the underlying strata. In Fig. 25 the formation favors the outcropping of springs; in Fig. 26 the opposite is the case.

FIG. 25.

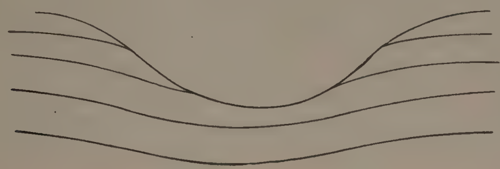
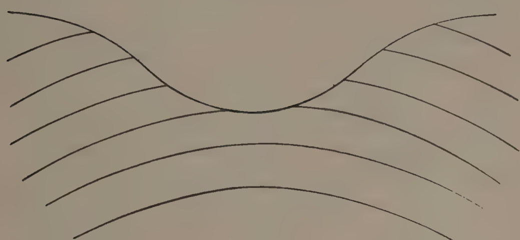


FIG. 26.



Wells may be classed as dug, driven, and bored. Sometimes they are divided also into *deep* and *shallow;* but these terms as a basis of classification are of doubtful utility, since there can be no general agreement as to the line of division between them, and because of the absence of any necessarily distinctive peculiarities in the water yielded by ordinary wells of different depths. It is not uncommon to meet with general statements that the water of shallow wells is dangerous to health, and should, therefore, be avoided, and that all shallow wells should be condemned and filled. As will be seen, however, shallow wells are not necessarily dangerous, nor are deep ones always safe by reason of mere depth.

By some writers, the term *deep* is applied to wells which obtain their water from below the first impervious stratum, through and beyond which they have been extended; while the term *shallow* is applied to those which draw from what we designate as the ground-water; that is, that collected over the stratum above mentioned, regardless of the depth at which it lies. With these meanings, it follows that a shallow well may extend farther downward than another classed as deep.

The ordinary dug well is a hole dug in the soil down as far as is necessary to reach water, and lined with brick or stone, or, better, with earthenware tubes of large diameter made for the purpose in short lengths with bevelled edges to secure good joints. All brick and stone linings should be well bedded in cement, except near the bottom, and should be faced with the same material throughout their upper part. The impervious lining is necessary for the prevention of the entrance of surface washings; but it is very generally the case, in some parts of

the country at least, that the well is lined simply with field-stones, without cement, not for the purpose of insuring freedom from surface impurities, but to prevent the sides from caving in. With a proper lining, no surface-water can enter until it has passed through a depth of soil sufficient to insure proper filtration and purification.

A dug well should not be left open, but should be closed completely against the entrance of dirt, leaves, and animals, such as toads, moles, mice, and rats. The cover should be supported on a well-set curb, and be sufficiently tight to prevent the return of water spilled or allowed to run to waste. A manhole with a trapdoor should be provided as a means of inspection and cleaning.

For bringing the water to the surface, pumps should be used, and not buckets worked by windlass or well-sweep. In country districts it is a common practice to employ buckets made from kegs, originally used as containers for white lead. It is hardly necessary to call attention to the injury which may be caused by the use of such vessels.

The pump may stand directly in the well or away from it and connected therewith by means of a pipe running laterally and downward. The latter is the better way, as any water wasted at the pump is prevented by location, if by nothing else, from running back into the well, and, moreover, the covering of the well, if of wood, is not continually subjected to wetting, which promotes its decay. The best form of pump is the simple lifting pump, made of iron or of wood, and consisting of an evenly-bored barrel, closed at the lower part by a valve opening upward, and a piston containing another. The upward stroke of the piston, by producing a vacuum, causes the water to pass through the lower valve, and its downward stroke forces the water confined in the barrel through the upper valve, and then the succeeding strokes lift and discharge it continuously. The old-fashioned chain pumps cannot be used without more or less chance of exposure to contamination from above.

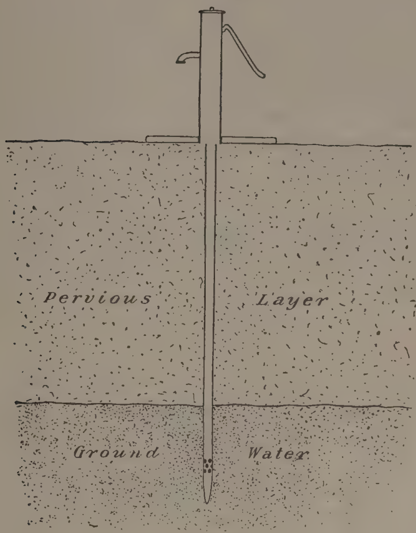
The action of the wind is very commonly employed as a labor-saver for pumping water not only from the well, but upward into reservoirs and distributing tanks. For this purpose a variety of wind-mills have been put upon the market.

There are also a number of makes of hot-air engines that are very efficient and not unduly expensive.

Driven wells, otherwise known as "Norton's tube wells," "American," and "Abyssinian" wells, are made by driving iron tubes of a diameter varying from $1\frac{1}{4}$ to 4 inches, according to the needs of individual cases, into the ground until water is reached. The first length driven in is provided with a pointed perforated foot, through which the water enters the tube. When this length is driven sufficiently far, another is screwed to it and the driving is continued, additional lengths being screwed on as necessary. When water is reached—and this is ascertained by means of a weighted string let down inside the tube from time to time—a pump is applied and the water lifted. The first that comes contains sand or fine gravel and dirt, and as this is more

and more removed from below, a pocket is formed which constitutes an underground reservoir.

FIG. 27.



Norton tube well.

Bored wells differ but little from tube wells ; in fact, they are practically the same except in the method of their making. They are drilled or bored through solid rock and other strata, and are lined or not with iron pipe, backed with cement according to circumstances. Their cost is much greater than that of the ordinary Abyssinian well, since the labor required is much greater. Sometimes it is necessary, after proceeding several hundred feet with no results, to resort to blasting at the bottom, so as to shatter the rock and form waterways to the well.

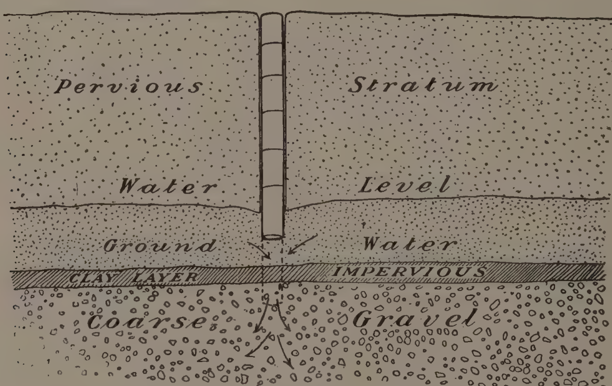
It is self-evident that wells of these two kinds last mentioned cannot, under ordinary circumstances, become contaminated with surface washings. Both forms are used very commonly not only for individual, but for public, supplies. In the latter case, they are driven in groups, or "gangs," the size of which varies according to the amount of water required. Increase in demand should be met by extension of the system rather than by over-forcing, for the latter will cause an undue lowering of the water level and tend strongly to bring water downward from the upper strata at such a rate as to preclude the purification which normally is brought about by the saprophytic bacteria of the soil.

In the case of an ordinary well, the bottom should be considerably below the level of the ground-water, so that when this falls, the well will not run dry, and also because the farther the withdrawal by pumping carries the level of the well below that of the water-table, the

faster will be the flow toward the well, and the greater the supply immediately available. But deepening a well for the purpose of increasing the supply sometimes has the very opposite effect, and may even cause it to run practically dry. Suppose, for example, the impervious layer is underlaid by a thick stratum of coarse gravel, and in the process of deepening the well this stratum is entered: instead of an increase in the supply, it then may happen that the water flowing into the well finds a ready exit downward by the force of gravity into the interstices of the gravel, and the usefulness of the well is terminated. (See Fig. 28.)

Included under bored wells are those known as *Artesian*. These are bored through impervious strata until a stratum is reached in which the water is under hydrostatic pressure sufficiently strong to force it to the surface, or at least to a point nearly as high, the rise

FIG. 28.



How a well may be spoiled by being deepened.

depending upon the height reached by the water-bearing stratum in higher land elsewhere. In Fig. 29 is shown a formation favorable to the obtaining of water by means of this class of wells. The water in the soil above the first layer of clay may be reached by sinking wells of the ordinary kinds. Below this is a second supply confined between two impervious strata inclining upward. The higher this formation extends above the level of the outlet *A* of a well sunk into it at that point, the greater will be the pressure at *B* and the higher the rise of the water. Thus, if it extends upward to *C*, for example, the water will not simply fill the tube, but will be thrown some distance into the air. In some cases, although the head developed is very considerable, the water does not come to the surface, because of the extent of leakage into the upper pervious strata of the soil.

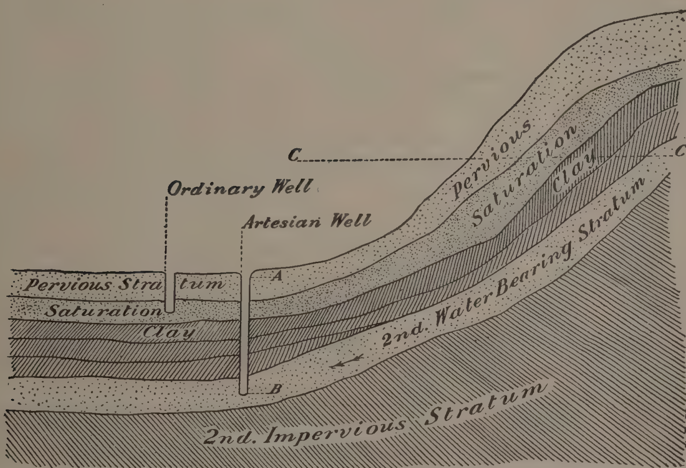
Sometimes the wells are connected with true underground rivers, and sometimes with apparently inexhaustible reservoirs which have held the water in storage for ages. Sometimes they derive their water

from fissures draining away the water of surface rivers and lakes, as is proved by the occasional occurrence in the overflow of small fish with eyes.

Artesian wells have been known in China and Egypt from very ancient times, and centuries ago they were introduced into the province of Artois (Artesium), from which their name is derived. They are exceedingly numerous in the western and southwestern parts of the United States, where they have produced enormous results in converting arid, waste lands into fertile farms. Some of them are exceedingly deep, and pass through stratum after stratum of different formations before water is reached.

Since the temperature of the earth increases 1 degree Fahrenheit for about 55 feet of depth, it follows that water from these very deep wells

FIG. 29.



Geological formation favorable to the obtaining of water by means of artesian wells.

is materially warmer than that from the upper subsoil. Distinctly hot water from deep sources is rarely fit for ordinary domestic purposes, because of the large amount of mineral matters present in solution by reason of the greater solvent power of water when hot than when cold. Thus they acquire an abundance of salts, which, taken into the body, influence its functions and act as medicines. The presence of organic matters is of importance on account of their reducing power. The sulphuretted hydrogen so common to mineral springs is due to the action of these matters on sulphates.

Irrespective of the changes wrought by increased temperature, the water yielded by this class of wells varies very widely in character. It may bear no resemblance whatever to the other waters of the same district, nor is there any reason why it should, for the conditions at the surface and at points hundreds of feet below are quite

different. Moreover, one cannot know how far the water has travelled from where it originally entered the soil to the point where it makes its escape.

Of waters from four such wells sunk within the limits of the city of Boston to depths of from 870 to 2,503 feet, two were extensively impregnated with common salt and other mineral matter, one was very rich in both vegetable and mineral substances, and the fourth was rich in both these and sulphuretted hydrogen.

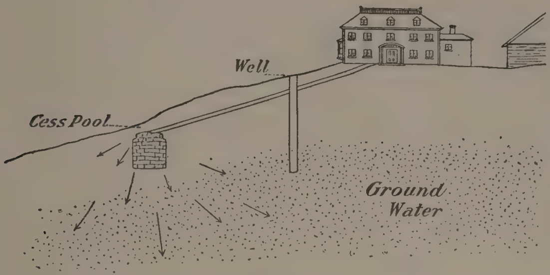
Drainage Area of Wells.—As to the amount of soil which is drained by a well, there can be no general rule. It is commonly asserted that the amount drained may be described as an inverted cone, having the bottom of the well as its apex, and a base with a radius equal to twice the depth of the well. But much depends upon the nature and configuration of the surrounding soil, and the extent to which pumping is carried. If the soil be sandy and open, the base will be much larger than if it be clayey and close. If extensively pumped, the well will drain a greater area than if the demands be moderate; in fact, the amount of water removed by pumping has a greater influence in determining the drainage area than mere depth. But other things being equal, the nature of the water-bearing stratum determines the distance to which the measurable influence of pumping is felt.

Pollution of Wells.—In general, it may be stated that, as between wells of different depths, the shallower are more subject to pollution than the deeper, because of the fact that the latter have the advantage of the greater opportunity for perfect filtration through the soil. But both are subject to pollution by unoxidized matters which enter the soil below the upper few feet in which the nitrifying organisms already referred to are found, as, for instance, from leaching cesspools and leaking drains. It is a practice only too common, even on estates of considerable size, where the excuse of limited area cannot obtain, to locate the well and the cesspool very near together. To avoid the necessity of having to remove the contents of the cesspool as occasion demands when this receptacle is made water-tight, and to avoid the expense attending this kind of construction, the bottom is generally left open, so that the house sewage may drain away into the surrounding soil. Connection between the cesspool and the well may take considerable time or may occur quickly, but, once established, contamination goes on uninterruptedly. Often it happens that the direction of the flow of filth through the soil is wholly away from the well, and contamination may never occur; but this is a point that can never be determined in advance.

It is a common belief that, if the well is located in higher ground than the cesspool, there can be no danger of pollution of its water. This, however, is a most fallacious proposition, for it is not so much the location of the outlet of the well that determines the possibility of pollution, as the relative position of the cesspool and the point where the water enters the well. In Fig. 30 is illustrated the manner in which the supply yielded to a pump placed at a point considerably

above the location of the cesspool is polluted directly by the liquid filth issuing from the latter. Again, the geological formation may be such that a cesspool on higher ground than the nearby well will have no influence on the purity of the water. Thus, a ledge of rock may crop up between them, as shown in Fig. 31, and divert the flow of polluting matters away from the well.

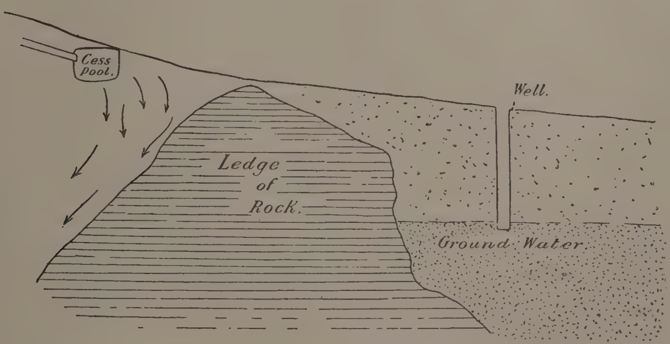
FIG. 30.



How a well located on high ground may be polluted by the contents of a cesspool lower down.

In locating wells and cesspools, property owners not infrequently lose sight of the fact that, while they can govern the disposition of the surface of their respective estates, the conditions that obtain in the soil below are quite beyond their control. In consequence, they may attempt to guard against pollution of their own water supplies by their own excretory products, without regarding the possibility of contamination by those of their neighbors.

FIG. 31.



How a cesspool located on high ground may fail to pollute a well lower down.

The water of newly dug wells is often of such a character as to lead to the perhaps false conclusion that it is probably polluted by sewage. It is generally turbid, and may, on analysis, yield results which, in case the analyst has not full information concerning it, may seem to warrant a condemnatory report. It may yield figures indicating a high content of organic matters, which may disappear as the use of the

water becomes established. It may even show undeniable evidence of the presence of human wastes, for those engaged in the digging and the stoning may be more interested in the completion of the work than in the perfect purity of the supply, and may be disinclined to go up to the surface for the purpose of relieving the calls of nature. On all accounts, therefore, it is better to await the results of a later examination, than to condemn and abandon too hastily a supply, which, within a short time, may prove to be of exceptional purity.

Very deep wells may become badly polluted by filth which gains access through open channel-ways, as fissures in rock. A good example of this is recorded in the *Sanitary Inspector* for December, 1896: A well bored 500 feet into red sandstone drained, through fissures, all the shallow wells in the vicinity. These being of no use as wells, were then utilized as cesspools, and, draining again through the fissures, caused the well to become so foul that it had to be abandoned. Dr. A. C. Houston[1] shows how deepening a well may, in a similar manner, cause its ruin. A well of pure water, 114 feet deep, was deepened by farther boring to 294 feet, when its yield was then found to be impure. At a distance of 800 feet was an old quarry, into which drained the sewage of 25 persons. By fissures in the sandstone, this reached the water stratum tapped by the extension of the well and thus spoiled the water.

On account of the possibility of contamination of shallow wells by the entrance of surface washings from above, Koch recommends that pipes be placed in position so as to reach the water stratum, and that then the wells be filled up, first with stone and coarse gravel, and toward the top, for at least six feet, with fine sand. By this procedure, the well is converted really into an Abyssinian well, and is protected from surface contamination quite as well as though it had originally been driven instead of dug.

Filter Galleries.—A *filter gallery* is a large underground tunnel sunk parallel to a river or lake and near to it; it is in reality nothing more than a horizontal well. The idea which led to their construction was that in this way the river water, percolating outward from its bed through the soil, would be secured in a filtered state, and would accumulate in the underground reservoirs. Although this method of obtaining water has been attended by most excellent results, the fact remains that the water so collected comes not from the river, but from the ground on its hither side; that is to say, it is the ground-water intercepted on its way to the river.

The water of a river does not, except under unusual conditions, percolate outward, for the silty matters deposited in its flow clog the interstices in the soil of its bed and banks, and act as a valve against its egress. The ground-water, flowing to the river, finds its way in through the silt, which gives way inward against the side of least resistance. Thus the silt yields to ingress, and is a bar to egress of water.

[1] Edinborough Medical Journal, Nov., 1894.

The fact that the flow of ground-water is toward rather than away from rivers and other large bodies of water is well shown by the fact that fresh water is obtainable from wells sunk in close proximity to high-water mark on the sea-coast. Such may be not even slightly brackish, although sometimes they are distinctly so by backward diffusion of the salts. In the latter case, removal a short distance backward obviates the difficulty.

That the water derived from a filter gallery is not due to percolation from the river along which it lies, is farther proved by the fact of difference in composition, and especially in hardness.

Classification of Waters from the Sanitary Standpoint.

From the standpoint of wholesomeness, waters may be divided into two classes: 1. Those free from sewage contamination. 2. Those polluted by sewage.

Unpolluted waters are not necessarily suitable for domestic use, presenting as they do, wide variations in character. They may be clear, colorless, odorless, and palatable, and contain but little organic and mineral matter; or they may have high color, turbidity, disagreeable odor and taste, and a high content of dissolved and suspended substances. A water which, by reason of appearance, odor, and taste, due, for instance, to luxuriant growth of algæ or other forms of life, is repugnant to the senses, should not be recommended for use, although incapable of producing a specific disease. Such an one requires no chemical analysis to determine its fitness, the evidence of the senses being quite sufficient.

Unpolluted waters free from such qualities as render them repugnant to the senses, and of low content of organic and mineral matters, are suitable for general purposes without regard to their classification as surface- or soil-waters. But, in general, it is held commonly that an unpolluted soft ground-water of good composition is preferable to one of surface origin.

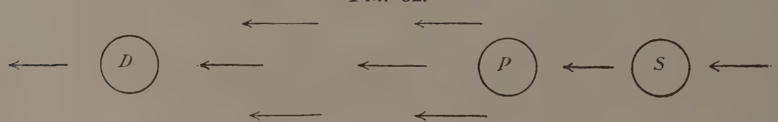
Polluted waters may be divided into two classes, according as the pollution is direct or indirect. Direct pollution by sewage is, it is hardly necessary to say, of prime importance, because of the danger of transmission of specific diseases and of lowering the physiological resistance of the system. But even direct pollution may be productive of no harmful results, provided sufficient time elapses between the entrance of the sewage at a given point and the use of the water at a distance to permit of the disposal of the noxious elements by natural processes. Thus, a volume of sewage entering the upper part of a large system of public supply may not reach the distributing pipes for several months, during which time its dangerous qualities will have disappeared. Notwithstanding this fact, however, direct pollution of drinking-water should be prevented by all means available, on account of possible risk, and even on æsthetic grounds alone.

Indirect pollution is of far less importance than direct. In indirect

pollution the organic matters of the sewage, including bacteria, are filtered through the soil, in which they are held back mechanically and more or less completely oxidized before the containing water reaches its ultimate destination. As to what may be called a safe limit of distance from sources of pollution, no fixed rule can be given: each case must be judged according to its circumstances. The soil as a whole has enormous capacity for purifying water of its contained organic substances and bacteria, both by mechanical retention and by oxidation processes set in motion by the bacteria which inhabit it. But all soils have not this power in an equal degree, and the conditions favorable to its exercise are not always present to the same extent. The soils most favorable for perfect filtration and purification are sandy and gravelly; in these, the water is exposed in thin layers on the individual grains to the air in the interstices. The latter should be neither too coarse nor too fine. If too coarse, the passage of water is too rapid; if too fine, not sufficient air can be present at the same time. The organisms are found only in the upper few feet of soil, and it is here also that the contained air is richest in oxygen. When the necessary conditions for filtration are present in a given soil, the water which percolates through and reaches the ground-water is quite free from bacteria of any kind, even though the surface is contaminated extensively. Where the soil is very open and permeable to water or fissured, polluting materials may pass through so rapidly that they undergo but slight change on the way, while with a not too fine soil, through which water passes with slowness, purification by bacterial action may be completed within a very short distance.

Again, there may be greater safety at a point quite near to, but on one side of a center of pollution, than at another at a considerable distance away on the other side, owing to the direction of the flow of water. Thus, in Fig. 32, the point *S*, located quite near the point of

Fig. 32.



entrance of the polluting material *P* into the soil, is far better situated in respect to possible contamination of water by *P*, than the point *D* on the other side but farther away, since the movement of the water in the soil is, as indicated by the arrows, from *S* toward *D*, and all impurities entering between the two move from the one toward the other. Similarly, the point *S* may stand in the relation of point *D* to some other polluting influence.

For the determination of the question whether a given well is receiving pollution from any given point, recourse is had to the diffusibility of coal-tar colors, such as fluorescein. An ounce of this substance will impart a very decided color to an enormous volume of

water; and when it is added to the contents of a leaching cesspool, it will accompany the escaping pollution and reveal to the eye the presence of the latter in any neighboring well-water. Pollution may thus be traced sometimes through hundreds of feet of fairly close soil.

Purification of Water.

Before proceeding to the consideration of methods employed to bring about purification of water supplies, a few words are necessary on the subject of "self-purification" of surface-waters. A river shows, for instance, at a given point in its course a certain amount of impurity; at another point farther down, this is found to be considerably lessened; and farther yet, the diminution is still more marked. This progressive lowering is attributed to the property the water possesses of bringing about its own purification. The practical beginning of this theory was the assertion, made, in 1869, by the British Royal Commission on Water Supplies, that sewage, diluted twenty times or more by river-water into which it is discharged, will be completely oxidized before it has travelled more than a dozen miles. Two years later, the Rivers Pollution Commission reported strongly against accepting this idea, and concluded that oxidation proceeds with such extreme slowness, even when the polluting matters are diminished very largely by pure water, that not only will a flow of a dozen miles not suffice, but that there is no river in the United Kingdom sufficiently long to accomplish the result claimed. It was then believed that whatever changes occur are the combined result of oxidation and subsidence. It is now recognized that these agencies, assisted by more important ones, namely, dilution, vegetation, and bacterial action, do in many cases produce very great changes, while in others the results are only partial and of no especial value. Drs. R. Emmerich and F. Brunner[1] showed that in spite of the large amount of sewage matters poured into the Isar in its course through Munich, the water after two hours' flow below the city was practically as pure chemically as it was before it reached it. Jordan[2] has shown that, after thirty-four miles' flow, the Illinois River is practically free from sewage bacteria. E. Duclaux[3] has shown the same to be true of the Seine, and other observers have proved it of certain other rivers in England, Germany, and elsewhere. On the other hand, opposite results have been obtained by other workers in the same field.

Oxidation undoubtedly plays a more or less important part in some, but by no means in all, cases. Dr. T. Meymott Tidy proved experimentally that water containing sewage could lose about half its organic matter in from six to nine hours when made to run one mile in glass troughs with abundant aëration. Professor William P. Mason,[4] on the other hand, agitated water in a bottle fastened to the connecting rod of a horizontal engine with a ten-inch stroke of 75 to the minute,

[1] Die chemischen Veränderungen des Isarwassers, Munich, 1878.
[2] Journal of Experimental Medicine, Dec., 1900, p. 271.
[3] Annales de l'Institut Pasteur, 1894.
[4] Water Supply, New York, 1897, p. 175.

and found that after 9,000 concussions there was but a trifling diminution in the amount of organic matter. A large measure of purification, so far as numbers of bacteria are concerned, is caused by agitation when there are solid particles in suspension in the water. This has been well shown by Percy Frankland,[1] who observed a decrease of 96.65 per cent. in the number of bacteria.

Dilution by access of rain, melting snow, ground-water, and other clean influents, affects chemical composition favorably, but assists, for a time at least, increase in the numbers of pathogenic and other bacteria. Professor Kebrehl's[2] daily bacteriological examinations of river-water at Prague proved that, in general, the number of bacteria increases with rising water, and is subject to very wide variations, due to a number of causes, among which he mentions changes in the rate of flow, with consequent alteration of conditions influencing sedimentation, and the influx of temporary pollutions, such as washings from streets and dung-heaps, which, under some circumstances, have greater influence than the regular unclean influents.

Sedimentation, which formerly was believed to play a very great part in the improvement of river-waters, acts to only a slight extent in those which, like the Isar, move swiftly. It is favored by slowing of the current, especially at the river mouth; and when it occurs it has a very marked influence on the number of bacteria, especially if the water be muddy. This has been shown by Bruno Krüger,[3] who, by a series of experiments, proved that chemically indifferent substances in a state of minute subdivision exert a greater influence, the more slowly, up to a certain limit, they settle; while other matters, which act both mechanically and chemically, such as lime and hard wood ashes, produce still greater effects. In still water, as small lakes and ponds, sedimentation goes on unobstructed.

Bacterial action as a purifying agent is favored by alkalinity and retarded by acidity. It may be important or not, according to circumstances. Destruction of pathogenic species by the saprophytic class is delayed by dilution by unpolluted water, which, as above stated, favors their increase for a short time, after which they rapidly decline in number.

Vegetation was not taken into account by the earlier observers, but has now been placed at the head of the important influences in the process. Pettenkofer[4] asserted that the greater part of self-purification is due to the growth of algæ and other low forms of vegetable life, which clean the water of its impurities in the same way that the higher forms take up and dispose of the manurial matters of cultivated land. This view is endorsed by T. Bokorny,[5] who proved that these plants

[1] Journal of State Medicine, January, 1894.

[2] Bacteriologische und kritische Studien über die Verunreinigung und Selbstreinigung der Flüsse. Archiv für Hygiene, XXX., p. 32.

[3] Die physikalische Einwirkung von Sinkstoffen auf die im Wasser befindlichen Mikroorganismen. Zeitschrift für Hygiene, VII., p. 86.

[4] Zur Selbstreinigung der Flüsse. Archiv für Hygiene, XII., p. 269.

[5] Ueber die Betheiligung chlorophyllführender Pflanzen an der Selbstreinigung der Flüsse. Archiv für Hygiene, XX., p. 181.

take up all manner of organic substances, including volatile fatty acids, amido acids, glucose, and urea. He showed that the water of the Isar contains vast numbers of algæ, to whose action much of the changes noted by Emmerich and Brunner were undoubtedly due.

Methods of Purification.—The methods employed for the purification of water embrace:

1. Chemical treatment.
2. Boiling and distillation.
3. Filtration.

1. **Chemical treatment** is employed to cause the formation of insoluble precipitates, which settle out and entangle suspended matters, including bacteria, in their descent.

Alum, for instance, added to the extent of a quarter of a grain to a grain per gallon of natural water containing a moderate amount of $CaCO_3$, is decomposed, and forms an insoluble gelatinous hydrate, which combines with the organic matters imparting color and settles out as a flocculent precipitate, which entangles the suspended matters, including the bacteria. The sulphuric acid, set free by the decomposition of the salt, unites with the lime or other bases present, and is thus neutralized, and the calcium sulphate thus formed carries down suspended matters in the same manner. If an excess of alum is added, it will necessarily appear in the purified water, and be objectionable on account of its effect on the system, and in the bath and in washing.

In case of deficiency in $CaCO_3$, lime-water sometimes is supplied, and identical results obtained. The addition of freshly precipitated alumina serves the purpose equally well, and avoids the presence of the sulphuric acid resulting from the decomposition of alum.

Alum removes practically all the bacteria, as has been proved by V. and A. Babes,[1] Professor E. Ray Lankester, and others. The use of alum in the purification of water is not of recent origin: it was described as early as 1830 by Felix d'Arcet,[2] who mentions its extensive use in Egypt.

Lime-water or milk of lime, added to water containing calcium carbonate held in solution by carbon dioxide, causes precipitation of the former by uniting with the latter. It thus withdraws the solvent from active service, causes precipitation of that which was held in solution, and, becoming itself converted to an insoluble substance, is precipitated. So a double precipitation occurs. But water thus treated is not necessarily limited in its changes to a removal of its excess of calcium carbonate, for, in the precipitation of this substance, considerable other matter may be carried down mechanically, and bacteria are lessened decidedly in number.

Permanganate of potassium is used more or less, particularly in wells in India during the prevalence of cholera epidemics. Enough is

[1] Centralblatt für Bakteriologie und Parasitenkunde, 1902, XII., p. 45.

[2] Note relative à la clarification de l'eau du Nil, et en général des eaux contenant des substances terreuses en suspension. Annales d'Hygiène publique, IV., p. 375

added to secure a slight pink tinge, which indicates a slight excess. This acts as an oxidizing agent with good results. For example, Dr. P. W. O'Gorman [1] relates that during an outbreak at Midnapore, the number of cases, 117, was supposed to have been kept down by its use. These occurred in all parts of the town, excepting in the European quarter and at the jail. The former used water which was filtered or boiled and filtered, and at the jail especial care was taken of the water supply. Forty-six public and private wells were disinfected with the salt, and the outbreak thereupon ceased. An ounce or ounce and a half or more, according to the size of the well, was dissolved in a bucket, poured into the well, and stirred about. If after half an hour the water showed a red tinge, it was considered that enough had been added; if not, more was added until a tinge was seen. According to Hankin,[2] enough of the salt to insure a reddish tint lasting twenty-four hours should be added; but care should be taken not to add so much that fish, frogs, and turtles, put into wells to keep the water clean, are killed and the water spoiled by their putrefaction. Dhingra [3] states that this method can be relied upon only under certain conditions, and even then its action is not continuous. The agent must expend itself first in oxidizing organic matter and nitrites before attacking organisms, which, for their destruction, require it in fairly strong solution. He believes the method to be fallacious in theory, defective in technic, and impossible of practical application.

Sodium hypochlorite, "chlorinated soda," and chlorinated lime, "chloride of lime," are sometimes used, but in the case of both not without great risk of imparting disagreeable taste. Moritz Traube [4] gives a simple method of purification by means of the latter agent, which, added to the extent of less than half a gram to a hundred liters, kills all bacteria within two hours. The excess of the agent is neutralized by the addition of somewhat less than half the amount of sulphite of sodium, which, added somewhat in excess, does no harm, since it is soon oxidized. The assertion is made that water thus treated possesses no disagreeable taste and has its hardness not appreciably increased.

The "Woolf" method consists in adding a 2 to 3 per cent. solution of salt decomposed by a current of electricity of sufficient strength. This is equivalent to adding the sodium hypochlorite itself, which agent, according to Hünermann and Deiter,[5] can destroy in ten minutes all typhoid, cholera, and coli organisms contained in a liter of water, when enough is employed to give 40 milligrams of effective chlorine. The sodium compound is more efficient than chloride of lime, for the whole of its available chlorine is almost instantly diffused through the water and acts at once. After purification, the chlorine is neutralized by means of sodium sulphite (140 of sulphite to

[1] Indian Medical Gazette, July, 1896.
[2] Ibidem, July, 1896.
[3] British Medical Journal, Aug. 17, 1901.
[4] Zeitschrift für Hygiene und Infectionskrankheiten, XVI., p. 149.
[5] Deutsche medicinische Wochenschrift, 1901, p. 391.

40 of chlorine), and the water is then practically unaltered in appearance, taste, smell, and hardness, but only when the amounts of the compounds to be added have been most carefully determined.

Chlorine as such is used also to some extent; but, although effective, it is open to the objections that apply to the use of the hypochlorites, of which it is the active agent.

Bromine also has its advocates as a chemical purifier, both on a small and on a large scale. Schumburg[1] recommends a process which is said to kill in five minutes nearly all of the ordinary bacteria and all pathogenic organisms found in water. He uses a solution of 20 parts each of bromine and potassic bromide in 100 of water, 1 cc. of which suffices to sterilize 5 liters of Spree water. After five minutes' contact, the bromine is neutralized with ammonia, and the result is a clear, tasteless, sterile water. Very hard waters and grossly polluted river and marsh waters require larger amounts, because of the presence of lime salts in the former and of ammonia in the latter, which combine with the bromine before it has opportunity to act as a germicide. With such waters it is necessary to add enough of the solution to produce a yellow tinge which will persist at least half a minute. In any case, whatever the amount of the bromine solution used, an equal volume of 9 per cent. ammonia water should be added. (In a later communication, sodium sulphite is recommended.) This process is recommended particularly for use in the army, and in the tropics, for ships' supplies, and for individual use in times of epidemics. A kilogram of bromine is said to suffice to sterilize 16,000 liters of ordinary water. In practice, however, the process has not met with a large measure of success. Schüder[2] has tried the scheme, and finds it unreliable. It was tested in the Soudan Expedition in 1898, but the difficulties attending its use were enough to lead to its abandonment.

Treatment with metallic iron in the form of borings and punchings is employed in a number of places in Europe with most successful results. The best known of the processes in which this agent is employed is that of Anderson, in which the water is delivered into long iron cylinders, on the inner surface of which are curved partial diaphragms which, as the apparatus slowly revolves, carry upward the pieces of iron, which fill about a tenth of the volume of the cylinder, and cause them to shower constantly downward through the water in its passage. The carbon dioxide in the water attacks the iron and forms ferrous carbonate, which, when the water is discharged into the open air, becomes oxidized and converted to ferric hydrate. This flocculent matter entangles much of the organic matters, including the bacteria, and then the whole is passed through sand filters, the effluent from which is very pure and practically sterile. The process is unnecessarily expensive, involving as it does, in addition to the first cost of the plant, considerable outlay for power and other items, while the same results in the end may be obtained by the more simple process of sand

[1] Deutsche medicinische Wochenschrift, March 4, 1897.
[2] Zeitschrift für Hygiene und Infectionskrankheiten, XXXVII. (1901), p. 307.

filtration alone. Moreover, it appears that with peaty waters, the organic constituents of which form soluble compounds with the iron, the results are unsatisfactory.

The use of ozone has been recommended as a very efficient method of sterilizing drinking-water, and experiments on a large scale have yielded favorable results. Experimenting on very small quantities with a Siemens-Halske apparatus, Weyl[1] found that 2.3 milligrams of ozone were sufficient to destroy 99 per cent. of the bacteria contained in 200 cc. of water from the Tegel Lake. With 3 and 4 milligrams, he obtained complete sterilization of 0.5 liter of water containing 6,000 bacteria to the cc. For purification on a large scale, the impure water is caused to percolate through a tower filled with pebbles, through which the ozonized air passes upward. The Siemens-Halske apparatus used will produce 20 grams of ozone in an hour. The bacteria are reduced at least 99 per cent. and the percentage of organic matter is greatly diminished, but the process is at present very imperfect, for more than 70 per cent. of the ozone produced is lost. The ozonized water, although free from odor, has an unpleasant taste, and with many persons its use causes derangement of the stomach. This fault necessitates further electrolytic treatment with aluminum electrodes, whereby aluminum hydrate is formed and the water is clarified and freed from ozone.

Sodium bisulphate has been recommended by Parkes and Rideal[2] in the proportion of 15 grains to the pint. They state that *B. typhosus* is killed within five minutes, but recommend a contact of fifteen minutes, in order to insure sterility. Warner[3] has found that this is sufficient to cause a striking reduction in the number of added germs, but not complete sterilization. In most cases, *B. typhosus* is destroyed in thirty, and *B. choleræ* in ten, minutes. Contrary to the statement that the agent imparts an agreeable acid taste, Warner finds that to some persons the taste is unpleasant, and to all would probably become irksome. Moreover, a person consuming 5 pints of water in a day would swallow 75 grains of the salt, which would tend to increase rather than to quench thirst.

Chemical purification of water sometimes occurs without the intervention of processes especially provided, of which fact Professor Leffmann[4] records a conspicuous instance. The Schuylkill River in the upper part of its course receives much refuse mine-water, and becomes impregnated with iron salts and free mineral acids. "In its course of about one hundred miles it passes over an extensive limestone district, and receives several large streams highly charged with calcium carbonate. The result is a neutralization of the acid and a precipitation of the iron and much of the calcium. The river becomes purer, and at its junction with the Delaware River, at Philadelphia, it contains

[1] Centrablatt für Bakteriologie, XXVI.
[2] Transactions of the Epidemiological Society, London, XX., 1900–1901.
[3] Public Health, July, 1901, p. 700.
[4] Examination of Water for Sanitary and Technic Purposes, Phila., 1895, p. 14.

neither free sulphuric nor hydrochloric acid, only traces of iron, and but a small amount of calcium sulphate. In this manner there is produced a soft water, superior to that of the river near its source, or to the hard waters of the middle Schuylkill region."

2. **Boiling and Distillation.**—Boiling as a means of purification has been practised from very early times, and, in fact, was advised by Hippocrates (460–377 B. C.) for the avoidance of enlargement of the spleen. This process is quite efficient so far as destruction of the micro-organisms is concerned, but it does not diminish the amount of organic matter. It does, however, reduce the amount of dissolved mineral matter, in that calcium carbonate held in solution by carbon dioxide is precipitated, and calcium sulphate, being less soluble in hot than in cold water, tends to separate out. Boiling is available only to a limited extent; that is, it is a process which can be carried out in the household, but not on a large scale before public distribution of water. Boiled water is not palatable until aëration has restored the proper taste, but this is easily accomplished by passing it from one vessel to another, or by agitation in contact with air.

Distillation constitutes a most efficient process for obtaining pure water. This process produces necessarily a sterile water, which, however, needs thorough aëration. In the apparatus used in the United States Navy, the steam goes to the condensers in company with air, so that condensation and aëration occur coincidently. While no bacteria from the original water can pass over into the distillate, other volatile matters can and do, and instances are common to prove that the distillate of a foul harbor water may produce nausea and diarrhœa in all who drink it.

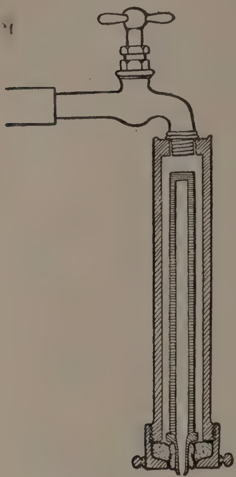
3. **Filtration** is a process of purification which is most efficient and available for large water supplies. It is employed on an extensive scale by numerous large cities in Europe and in this country. Before describing the process, however, it is in order to consider filtration in the household.

DOMESTIC FILTERS.

The domestic filters in common use are, as a rule, useless except for the removal of suspended matters, such as iron-rust, dirt, and other coarse particles, and worse than useless in respect of bacteria, the removal of which is claimed but not accomplished, in that they engender a false sense of safety, while they favor the growth and multiplication of organisms. Most of them are small affairs for attachment to a water faucet, filled with a filtering medium of coarse sand, animal charcoal, sponge, ground glass, wool, felt, and other substances which strain out the visible suspended matters not a whit better than the simple flannel bag in common use in New England and elsewhere a quarter of a century ago. They permit the passage of a good stream, and this fact itself is proof of their inefficiency as bacteria filters, for any material sufficiently coarse to permit rapid passage of water is not sufficiently fine to hold back such exceedingly minute suspended matters as bacteria.

Most of the materials used become very foul in a short time, and in consequence the water is richer in bacteria on issuing than it was before entrance. Theoretically, animal charcoal, on account of its oxidizing action, should be an ideal filtering medium, and at first it will remove a large proportion of the bacteria and more or less of any coloring matters. But very shortly it becomes foul; the calcium phosphate which it contains is of great assistance to the growth of bacteria; cleaning is impossible, and the effluent, if stored, soon becomes very foul and unpleasant.

FIG. 33.



Chamberland-Pasteur filter.

The only domestic filters worthy of the name are those which remove mechanically all the bacteria of the water and, at the same time, add nothing of their own substance to the water. Such are the Chamberland-Pasteur, the Berkefeld, and others based on the same principle. In these, the filtering medium is unglazed, well-baked, hollow, porcelain cylinders closed at one end like a test-tube, enclosed within a metallic or glass jacket, with sufficient intervening space for the water, which enters directly from the tap under its usual pressure or "head." The open lower end of the cylinder discharges the water, which passes directly through the walls of the cylinders, or "bougies," in the same way in which it would go through blotting-paper. The material is such a very fine strainer that it excludes all suspended matters whatsoever. (See Fig. 33.)

The bougies of the Chamberland-Pasteur filter are made of well-baked kaolin of the proper degree of porosity and hardness; formerly those of the Berkefeld filter were made of a soft friable infusorial earth peculiar to Germany, called Kieselguhr, but as they were very brittle and very liable to fracture while being cleaned, they are now made of a special blend of clays used in the manufacture of the finest porcelain. Bougies of other makes are of porcelain of varying grades.

All these filtering tubes are purely mechanical in their action, and remove none of the matters, poisonous or otherwise, in solution. While they remove and retain on their external surface all the bacteria, they cannot prevent the growth of the organisms from without inward through their walls, and, indeed, this occurs so quickly that, in order to secure absolutely sterile water continuously, it is necessary to clean and sterilize the bougies daily, and thus it is advisable to have two sets, one of which can be cleaned while the other is in use.

It has been proved repeatedly that normal water and water artificially and extensively infected will yield on the first day of the use of a clean bougie a perfectly sterile filtrate, and that on the second or third day a very small number of bacteria will most likely be present; but these are invariably ordinary water bacteria, and if the pathogenic varieties occur in the filtrate, they come considerably later. Repeated

experiments with water infected with *B. coli communis*, *B. typhosus*, and *B. choleræ* have failed to prove the passage of any of these organisms, while the ordinary water bacteria go through very readily. To secure a regular supply of wholesome if not completely sterile water, it is, therefore, sufficient to clean the tubes by scrubbing and boiling or by baking about twice a week. It appears, however, that the Chamberland-Pasteur and Berkefeld bougies are not equal in efficiency, for Horrocks[1] has succeeded in growing *B. typhosus* through the walls of the latter. He attributes this result to the larger size of the lacunar spaces and to the consequently diminished immobilizing and devitalizing influences. Since the shortest time required for the bacilli to traverse the bougie is four days, sterilization by means of boiling water should be carried out every three days, in order to insure complete safety

In general, the requirements of a satisfactory domestic filter may be stated as follows: It should yield a sufficient supply of clear, colorless water, free from taste derived from the filter itself; should arrest all bacteria and their spores; and should be simple in construction, and offered at a low price. Thus far, those made on the principle of the Chamberland-Pasteur filter have met these requirements best. Their introduction into use in the French army in 1889 was followed within two years by a reduction of more than 50 per cent. in the number of cases of typhoid fever occurring therein.

Filtration of Public Supplies.

Filtration on a large scale is accomplished by the aid of fine sand in filter beds of proper construction, which act both mechanically and biologically. The first beds of which we have accurate knowledge were those constructed by Simpson in London, in the year 1829, which were intended primarily for the removal of dirt and other suspended matters causing turbidity. The process was regarded at that time as a purely mechanical one, and though in course of time this kind of filtering medium came into very extensive use, it was generally believed that as carried on there was no marked chemical change in the water, and that what did occur was attributable to oxidation of organic matter by air in the interstices of the sand. This was, indeed, the view held generally up to the time when the extensive researches begun by the State Board of Health of Massachusetts in the summer of 1887 proved the great influence of biological agencies, although it had been shown by Meade Bolton, Heræus, Plagge, Proskauer, and others, that filtration removed all but a trifling percentage of micro-organisms, and that water bacteria exerted some influence on the amount of the usual constituents of water.

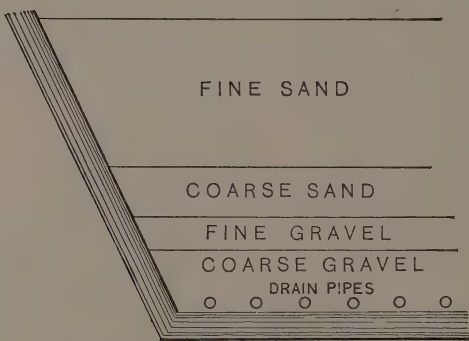
Although sand filtration of public supplies is of comparatively recent origin, its use for individual house supplies antedates Simpson by at least a century and a half, for Portius,[2] writing in 1685, relates that

[1] British Medical Journal, June 15, 1901, p. 1471.
[2] De militis in castris sanitate tuenda, auctore Luca Antonio Portio, Vienna, 1685.

the Venetians were accustomed to filter their drinking-water through layers of sand within their cisterns, in order to rid it of disagreeable odor and taste.

The first beds constructed by Simpson were broad basins twelve feet in depth, with impervious bottoms and sides, containing layers of stones, gravel, and sand, which occupied half their depth. Beneath the stones were laid ordinary drain pipes, through which the filtered water was discharged. As the top layers of sand became clogged, they were scraped and renewed. The beds of the present day are constructed on very similar lines. They are virtually immense tanks of varying size, shape, and construction. The walls are sometimes vertical, but more often sloping, sometimes built of stone or concrete, and sometimes consisting of ordinary embankment. Upon the paved bottom of a bed is laid a system of perforated or disjointed drain pipes leading to a central culvert or well, from which the filtered product is drawn. Above the drains are successive layers of coarse gravel, fine gravel, coarse

Fig. 34.



Partial vertical section of one form of filter bed.

sand, and, at the top, one of fine sand from three to five feet in depth. (See Fig. 34.)

The fine sand is sharp-grained in character, such as is obtainable at the seashore, and it should not contain clay or other material of similar minuteness of particle; if present, such should be removed completely by thorough washing. As to the size of the sand particles, it may be stated generally that the finer the grain, the better the effluent; but, it should be added, the more rapidly it becomes clogged and the more frequently it needs to be scraped off, and finally, the more difficult it is to wash for future use. With the finest sands, the bacteria are removed absolutely, but filtration proceeds so slowly that their use is not practicable. The most effective size of grain is a matter on which opinions differ; but whatever the size adopted, it is important that care be taken to insure uniformity. It is stated variously to be from a fifth to one millimeter in diameter, that is, the diameter of a sphere in volume equal to that of the grain

without regard to the shape of the latter. The higher figure is the one adopted by the authorities at Hamburg.

Before the water is applied to the bed, it may be advisable—and if it is from a turbid river, it will be necessary—to allow it to stand several days in a settling basin or reservoir, in order that the suspended matters may subside, and thus the too rapid clogging of the interstices of the sand with mud be prevented or retarded. Observance of this precaution will result in lessened necessity of frequent cleaning. Not only are the suspended matters lessened in amount, but organic matters in solution may be destroyed more or less completely by bacterial action, and the bacteria, too, may be diminished in number by being carried down with the settling matters with which they are in contact, and by the death of the less hardy varieties. In the case of waters from ponds and lakes, the preliminary sedimentation proceeds *in situ* and the settling tank is not needed.

The water is delivered continuously at the surface of the bed by devices automatically regulated, and percolates downward through the various layers of sand and gravel to the outlet pipes. Except with very fine sands, the first water of the effluent is not much, if any, purer than the original, but in a short time a sediment layer is formed on the surface and a slimy algoid growth occurs. This superficial layer acts both mechanically and by its contained bacteria to cause the removal and oxidation of organic matter and destruction of bacteria. The resulting effluent is quite pure and practically sterile. The Lawrence filter, for instance, removes more than 97.50 per cent. of the organisms present in the water as delivered, and the reduction is still more marked at the house service pipes, where 99.17 per cent. is recorded, the increase in purification being supposedly due to the fact that their necessary food material has been removed, and hence they cannot long survive. At Hamburg, Altona, Stuttgart, London, and other places, the reduction in bacteria is about the same as at Lawrence.

All organic matters are not acted upon to the same extent during filtration; some are decomposed very rapidly and mineralized, while others are attacked so slowly that complete removal during the short period elapsing between entrance and exit is often quite impossible. This latter class includes the brown coloring matters so commonly present in surface-waters. These are very stable compounds: they persist during long storage and are nitrified but slowly. In the process of chemical treatment with alum, however, they are coagulated and removed very quickly.

The slime layer, mud layer, or "schmutzdecke," is believed by some to constitute the sole actual filtering medium, the sand beneath acting only as a means of support. But experiments conducted at Lawrence and elsewhere show that this is not true, and that if the greatest care be exercised not to disturb the immediately underlying sand, almost the whole of the slime layer may be stripped off without causing any change in the bacteria count. The greater part of the

work is done in the upper layers of the bed, and yet bacterial efficiency is not necessarily established as soon as a coating has been formed. A perfectly new filter does not show its best results until it has been in use for some little time, during which the sand particles for a considerable depth become coated with the jelly-like deposit.

The active agents in bringing about the death of the bacteria contained in the effluent and in accomplishing the destruction and mineralization of the organic matters are of the same class of nitrifying organisms as are constantly at work in the soil. The death of the bacteria is not directly due to the process of nitrification, for it has been proved that a very marked increase in the process is not necessarily accompanied by any diminution in the number of organisms which manage to pass through to the drains. It is possible that the supposed relation of cause and effect is merely a coincidence of conditions, that is, that the conditions favorable to nitrification are unfavorable to the vitality of the ordinary bacteria. It is also possible that through nitrification the latter are deprived of at least part of the food materials necessary to their continued existence and multiplication.

Nitrification sometimes ceases suddenly after it has been proceeding for a long time at a proper rate, and then, after an interval, begins again without apparent reason. One explanation offered is that the process begins only when a certain amount of nitrogenous matter has accumulated within the interstices, that it then proceeds until the store is consumed, and that pending a further accumulation the process lapses. In winter it does not begin again until the temperature of the effluent reaches at least 39° F., but after it is once started it is unaffected by a fall to 35°. The most favorable temperatures for the process are those of the hot summer months.

As to the rate of filtration, it is important that, whatever the rate, it shall be uniform all over the filter. It has been proved by the Massachusetts State Board of Health that 2,000,000 gallons per day can be filtered through each acre of filter bed with the removal of substantially all the bacteria originally present. The Imperial Board of Health of Germany fixes 2,500,000 gallons per acre as the maximum amount permissible. Koch's three rules of filtration are that the rate of downward movement should not exceed 100 millimeters an hour, that the filtrate of each section should be examined daily while the bed is at work, and that filtered water containing more than 100 bacteria to the cc. should not be allowed to enter the pure water reservoir, but should be rejected or refiltered. The bacteriological test is much superior to chemical analysis for watching the efficiency of a filter, and a simple count is quite sufficient without attempting to identify the species.

When the filter begins to discharge slowly on account of the extent of the algoid growth at the surface, it is not safe to increase the pressure unduly by flooding the bed with an increased depth of water, for, as was shown by an experience at Berlin, such a procedure may force

the bacteria, which have accumulated largely in the meshes of the growth, down through the filter at such a rate that they are not destroyed by the usual agencies. In this case the water level was raised two feet, with the result that the portion of the city which was supplied with the water of that particular bed was visited by an epidemic of typhoid fever. The same sort of accident occurred at Altona some years ago, when, a year after successfully going through the cholera epidemic which devastated the neighboring city of Hamburg so extensively, a defect in the filter beds was followed by an outbreak of cholera, which disease had then died out in Hamburg.

When the sediment layer becomes so thick and dense that with the maximum pressure allowable the required amount of water fails to pass, it becomes necessary to scrape off the inch or so that has formed, and then to proceed as though the bed were new.

It will require, as a rule, several days for the formation of a new sediment layer, and until it is well developed the effluent should either be rejected or pumped back. The frequency with which a bed will require to be scraped depends upon individual circumstances, such as the size of the grains, the character of the water as applied, the rate of movement, the season of the year. The removal of the top is not difficult. It is quite compact and distinct from the sand beneath it, and is readily pared off with shovels or other tools. Successive cleanings may take place without replacement of the sand, until the depth of the filtering material is reduced to about 15 inches, but not below 12. The scraped-off sand may be washed thoroughly in a machine for the purpose until a sample in a beaker yields no turbidity to clean water, and it may then be stored until needed for future application.

Experiments have been tried repeatedly in Massachusetts, Berlin, and elsewhere in sterilizing sand by boiling it in water or otherwise subjecting it to high temperatures, and then determining its efficiency. The results have proved invariably that more bacteria are found in the filtrate than in the original water, and this is explained by the supposition that the bacteria that enter find in the cooked organic matter a food supply most favorable to enormous multiplication, and that the bacteria in the washed sand are necessary for the destruction of organic matter and of some of the varieties of water bacteria.

During and immediately after the scraping process, the bed is necessarily out of use, and, therefore, it is necessary, in order to insure continuous filtration, to have a number of separate beds, and to scrape them in turn. In this way, while one is out of use, the others can carry on the work.

In cold weather, owing to increased viscosity of the water, the rate of filtration is less than in the warmer months. In very cold climates, the formation of thick ice makes proper cleansing of the surface impossible; and imperfect scraping causes imperfect filtration. The removal of the ice augments considerably the cost of maintenance, and this item alone is one of sufficient importance to warrant the expense of covering the beds. But aside from cost, the efficiency of the process

is so much greater and the danger of epidemics of water-borne disease is so much diminished that the plant in a cold climate should always be covered. With an uncovered filter subject to freezing temperatures, imperfect filtration is almost sure to occur periodically, and this is indicated by an increase in the daily bacteria count. Thus, Wallichs [1] has noted that after freezing had occurred in the filters of Altona in February, 1886, January, 1887, February, 1888, and January, 1891, the number of germs in the filtered water rose considerably, and in each instance, in the following month, there was an unusual increase in the amount of typhoid fever.

Freezing of the surface causes imperfect filtration by bringing it about that the bed is overworked in those places which are still pervious. The application of water to the frozen surface thaws the ice slowly and unequally, and where the filter is active, it is doing the work of its frozen neighboring areas.

Scraping of a bed below the ice cake is performed with a machine which runs between the sand and the ice, cuts the layer and receives it in a bag as fast as it is removed. It is dragged from side to side without breaking the ice above it.

Covering a filter is advantageous in another direction, for by the exclusion of light, growths of algæ are inhibited, and there is, therefore, less need of frequent cleaning.

On the other hand, open filters get the benefit of the sterilizing influence of direct sunlight, but this is more than offset by the promotion of luxuriant growth of algæ and other microscopic plants in the warmer months. It is sometimes hardly possible to keep filters in good working order in summer owing to these growths, which clog the interstices very quickly and cause diminished efficiency just at a time when the demand for water is greatest. The coincidence of greater demand and more frequent cleaning does not permit of sufficient intervals of rest after the completion of the scraping process.

In what is known as "intermittent filtration," the filter bed is used for the reception of water during part of one day, say sixteen hours, or even during several days, and then is allowed to drain off and rest for a while. As the water drains away, the interstices of the sand become filled with air, that is, the bed becomes aërated, and thus the nitrifying bacteria which bring about the destruction of organic matter and its subsequent mineralization to nitrates are assisted to maintain their vitality. The intermittent process is superior to the continuous in that nitrification proceeds more strongly, the organic matter is, therefore, more completely removed, and the ordinary bacteria do not survive so long in aërated sand; but, on the other hand, it is inferior in that, being so much out of active use, the main plant needs to be so much the larger for the accomplishment of a given amount of work. As a matter of fact, however, all sand filters are at one time or another intermittent, since each time a bed is scraped the water is drained away, and the space formerly occupied by it is then filled with air. Sometimes

[1] Deutsche medicinische Wochenschrift, 1891, p. 25.

it is proposed to put the water through a process of double filtration, that is, to pass the filtrate on to another bed for still further purification. But if the first filtration has been carried out properly, the filtrate will have been deprived of all the materials necessary for the formation of the real filtering surface on the second bed. Thus the passage of the water through a second filter would be much in the nature of a mere form, for it would pass practically unchanged.

Sand filtration, when properly managed, has proved itself so efficient that the number of cities and towns making use of it is growing almost daily. Although protection of a supply at its source may be preferable to pollution followed by sand filtration, it is not always so trustworthy, since pollution may creep in by accident at any time in the best guarded supplies. The ideal course is protection at the source, followed by filtration before distribution. This is the method now adopted by the authorities of a number of cities in Europe.

"**Mechanical Filtration.**"—In some places, particularly in the United States, the water supply is treated in what are known as mechanical filters, of which there are a number of varieties, all based on a common principle. Such a machine consists chiefly of an iron or wooden cylinder filled with rather coarse sand or crushed quartz, through which the water passes by gravity or is driven under pressure at a much faster rate—from 50 to 150 times faster than it moves in a bed. To take the place of the sediment layer which forms in the latter, an artificial film is produced by the use of alum as a coagulant. This is formed quickly and serves the same purpose, though not with the same thoroughness. The filter is called *mechanical* only because power and mechanical devices are employed in regulating the rate, pressure, the application of the alum solution, and the raking and shaking of the sand in the process of cleaning, which process it is necessary to carry out at short intervals. Instead of removing the top layer, the whole body of sand is thoroughly agitated and washed. Filtered water is pumped through from below for five or ten minutes, and the sand layer is agitated by revolving rakes or by compressed air introduced from below. The process is not suited to all water supplies, but for the highly colored and turbid waters so common in the South and West it is particularly well adapted, and is cheaper, more efficient, and more easily managed than filtration through beds of sand. With careful management, upward of 99 per cent. of bacteria are removed.

Destruction of Algæ.

For the destruction of overgrowths of algæ, Moore and Kellerman[1] recommend the use of copper sulphate in extreme dilution (about 1 part of the crystals to 4 or 5 millions of water). In the practical application of this agent to ponds or reservoirs, the crystals are placed in gunny sacks, which are then drawn through the water by means of row-boats, which traverse the area in concentric lines from 25 to 40 feet

[1] U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 64.

apart. The process has been tried in various places with results varying from complete success to utter failure. In some instances, the destruction of one species of algæ has been followed by overgrowths of equally objectionable and more hardy forms. The assertion that the copper is quickly precipitated is disputed by many who have given the process a trial, and the claim that pathogenic bacteria are destroyed with the algæ appears to have little, if anything, to support it.

Removal of Hardness.

On account of the enormous waste of soap as well as loss of time which the use of hard waters in washing entails, and of the injury to which boilers and hot-water pipes are subject from their action, it often becomes necessary to apply some remedy whereby the degree of hardness may be lessened. This may be accomplished by the aid of heat or by the addition of chemicals. Boiling, as we have seen, drives off the contained carbon dioxide and causes precipitation of the carbonates which have been held in solution by this agent, but it has no effect on the salts which cause the permanent hardness. For use on a large scale for public supplies, this means is hardly applicable, on account of the cost of plant and of fuel; but for domestic purposes the cost is comparatively slight, in that the fuel necessary in cooking may be utilized coincidently for the purpose of heating water. For the chemical treatment of hard waters, the first process devised was that of Clark, patented in 1841. This process is based upon the affinity of caustic lime for carbon dioxide, with which it forms the practically insoluble carbonate.

On the addition of lime water to water containing chalk and magnesium carbonate held in solution by carbon dioxide, the reaction occurs, and a double precipitation of the carbonates present and of that formed is brought about. The process is very economical so far as cost of material is concerned, in that a few cents' worth of lime will remove an amount of hardness which will decompose many dollars' worth of soap. Lime water, however, does not affect the chlorides and sulphates, and hence, like boiling, reduces only the temporary hardness. For the employment of this process on a large scale, various forms of apparatus have been invented, consisting of chambers, or tanks, in which the lime is mixed with water and from which the mixture passes into other large receptacles, wherein it meets the water to be treated. Thence, according to the nature of the apparatus, the water passes on to settling tanks or to mechanical filters, where separation of the precipitate is completed. The largest plant of this kind in the world is located at Southampton, England, where 2,000,000 gallons of water are treated daily at what may well be regarded as an almost insignificant cost. The building in which it is installed covers less than a seventh of an acre, and is sufficiently large to accommodate additional apparatus whereby its working capacity may be increased by half. Whatever the forms of apparatus employed, the process must be carefully supervised, and the amount of lime added must be constantly regulated; for if too

little is employed, the full extent of possible softening is not reached, while with too much, the water is made alkaline and the carbonate of magnesium is retained.

Caustic soda may be used for softening waters containing carbon dioxide and the salts causing permanent hardness. Added in proper amount to combine with all of the free carbon dioxide, it forms carbonate of sodium, which, in its turn, attacks and decomposes the other salts and causes their precipitation. Sodium carbonate itself may be added in the absence of free carbon dioxide to bring about the same result. In some processes for softening water, both lime and caustic soda or sodium carbonate are employed, the object being the reduction of both temporary and permanent hardness.

Removal of Iron.

Some ground-waters contain iron in such amounts as to be objectionable, both on account of its influence on the system and because of its production of stains on linen and other textiles in the laundry. There are two principal methods of removing it, both of which depend upon the conversion of the ferrous compounds into the ferric form, with consequent separation as a precipitate. These are filtration and aëration. Filtration may be conducted through sand or coke or animal charcoal, and with either material the iron in solution is exposed to the action of air in the interstices and becomes oxidized to the sesquioxide, which is left on the filtering material. If the air supply is insufficient, and if there is much organic matter present in the water, the sesquioxide may be reduced to the ferrous form and again pass into solution. When ground-water containing less than 3 parts of iron per 1,000,000 is exposed in large volumes to air, the iron will settle out almost completely within a day or a day and a half.

Another method of removal by chemical treatment involves the use of ferric chloride and caustic lime in the proportion of 1 and 5 to 10 grams respectively to each 100 liters of water. By this, the "Kronke" method, all the iron can be removed, but it necessitates the use of a mixing tank, constant attention, and eventual filtration for the removal of the precipitated iron.

Action of Water on Lead and Other Metals.

Action on Lead.—The question as to the best material for house-mains and distributing pipes is always an interesting one, and never more so than when a considerable number of persons in a community begin to show symptoms of lead-poisoning, and evidence is presented which incriminates the water supply. Aside from the matter of cost, the advantage of using lead pipes lies in the comparative ease with which lead is worked, since it may be bent to any necessary extent, and thus may be fitted to all manner of irregularities of construction without the need of the frequent cutting, thread-making, and coupling, which the use of inflexible material involves.

All ordinary waters have a greater or lesser tendency to attack lead, according to the nature and amount of the substances held in solution. The commonly accepted statement, that pure soft water is prone to attack lead, and that hard waters tend to protect it by forming incrustations over the exposed surface, is true only in part, for some very pure soft waters exert only very slight action, while some very hard ones act with unusual intensity.

Waters containing very small amounts of organic and mineral matters act or not, according as they contain much or little dissolved oxygen or carbon dioxide, or both.

A chemically pure water would probably exert no action whatever on chemically pure lead, but commonly neither the one substance nor the other is seen in such a state of purity. Ordinary distilled water, however, which is a nearer approach to absolute purity than any other natural water can be, will, under certain conditions, act very corrosively, the conditions being the presence of the above-mentioned gases. It is held generally that either oxygen or carbon dioxide alone in water has but little influence, but that the two together act with varying intensity up to a certain point, directly proportionate to the amount of carbon dioxide. This belief, based on experimental observations of Müller,[1] was strengthened by Drs. Antony and Benelli,[2] who found that the highest results in lead corrosion were obtained by the use of aërated water charged with carbon dioxide. Investigating the plumbo-solvent property of a particular water, A Liebrich [3] came to the same conclusion: that the simultaneous presence of air and carbon dioxide favors action, while either alone has no power. Recently, however, a very extensive inquiry into the subject of metallic contamination of water supplies has been conducted by Mr. H. W. Clark,[4] chemist of the State Board of Health of Massachusetts, whose results indicate that oxygen is the more actively corrosive, and that either gas can act alone. He employed distilled water, freed in the first place as completely as possible from these and all other gases, and then impregnated with known amounts of either or both. Clean bright lead pipe in equal amounts was placed in half-gallon bottles filled with water containing the gases in the proportions stated below, then sealed and set aside at a temperature of 68° F. for one week, at the end of which time the amount of lead taken up was determined. The results are shown in the following table:

No.	Gases present.	Amount of lead taken up (parts per 100,000).
1	Oxygen to saturation	2,4100
2	Carbon dioxide 4 parts per 100,000	0.4993
3	Carbon dioxide 20 parts per 100,000	0.8935
4	Oxygen $\frac{1}{10}$ of saturation, CO_2 4 parts per 100,000	0.0861

[1] Journal für praktische Chemie, Series 2, 36, p. 317.
[2] Gazetta chimica italiana, Jan. 21, 1896, p. 275.
[3] Zeitschrift für angewandte Chemie, 1898, p. 703.
[4] Annual Report for 1898, p. 541.

A specimen of lead in a bottle containing water from which the oxygen had been boiled out as completely as possible, and the carbon dioxide removed by barium hydrate, was kept at 82° F. for a week unchanged. At the end of the second week, slight action was discernible in spots on the surface, and analysis showed 0.0774 part per 100,000 of water. A specimen of ordinary distilled water in a bottle with a small air space in the upper part attacked a similar piece of lead pipe to such an extent that it yielded 10.58 parts per 100,000. In this case, the temperature at which the water was kept was 81° F.

Inasmuch as all drinking-water contains more or less air in solution, oxygen is always present in some amount, and since, furthermore, carbon dioxide is also generally present, it follows that, unless substances with a decidedly deterrent influence are present, more or less corrosion is to be expected. Numerous instances of chronic lead-poisoning due to water rich in carbon dioxide are on record. At Sommerfeld,[1] for instance, where, in 1888, numerous cases occurred, it was found that the very pure water, rich in this gas, dissolved lead to the extent of about 6 milligrams per liter. At Lowell, Massachusetts, numerous cases were observed during the years 1898 and 1899, and it was discovered that one source of supply was rich in dissolved oxygen, and that the other, which caused by far the greater number of cases, was rich in carbon dioxide.

Professor A. W. Hoffmann believes that a moderate amount of carbon dioxide lessens corrosion by forming a protective coating of carbonate, but that an excess of the gas dissolves it as bicarbonate. The gas is said also to have no action on lead coated with suboxide.

Water containing free acid of any kind attacks lead. Sulphuric acid, which is supposed erroneously to form an absolutely insoluble compound, the sulphate of lead, is particularly active. In the ordinary chemical sense, sulphate of lead is insoluble in water; but in the hygienic sense, it is sufficiently soluble to be capable of producing serious symptoms. This acid is not an uncommon constituent of water in minute amounts, especially in the vicinity of cities and large towns, where it exists in the atmosphere as an impurity due to the combustion of coal. The peat acids also have considerable action on lead, but they are not always present in waters from peaty deposits. Some very brown waters appear to exert but slight action, while others are intensely corrosive. The peat acids are due supposedly to the growth of certain micro-organisms found in peaty soils, for a neutral sterilized decoction of peat to which a small amount of fresh peat is added will in a short time develop an acid reaction and ability to dissolve lead. Liebrich [2] reports a peaty water poor in carbon dioxide and carbonates which took up 300 parts of lead per 100,000 over night, and more when calcium carbonate was added.

The ammonium compounds and the nitrates have been supposed commonly to have a marked corrosive action on lead. That this sup-

[1] Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, Suppl. XXIV.
[2] Zeitschrift für augewandte Chemie, 1898, p. 703.

position is correct, has been proved amply by Mr. Clark's researches; but intense action is manifested only when the water containing them is exposed to air.

The constituents of water which tend to bring about corrosion of lead are, then, carbon dioxide, oxygen, ammonia, nitrates, and free acids. The substances which, on the other hand, exert a protective action include chlorides, carbonates, and silicates, and, probably, sulphates. According to Crookes, Odling, and Tidy, 0.5 grain of silica to the imperial gallon is sufficient to afford complete protection in all but exceptional cases, even when free acids are present; but certain waters containing considerable amounts of silica are known to be corrosive to a decided extent. The protection due to silica may be obtained by allowing the water to flow through broken flint, flint and chalk, or limestone, but such treatment sometimes has the undesirable effect of increasing corrosive power.

Sodium and calcium carbonates are very efficient. The bicarbonate of sodium is generally present in those very soft waters which have the slightest action; calcium carbonate is efficient whether or not carbon dioxide is present in the water at the same time. Four grains per gallon are generally considered to be quite sufficient to afford protection under most circumstances. As an illustration of the influence of this agent, may be cited the fact that the very pure water with which Glasgow is supplied has, before its entrance to the aqueduct, a marked plumbo-solvent property, but loses it entirely in its passage to the city, owing to contact with this substance. In 1887, the water of Dessau was treated successfully with calcium carbonate. Sodium carbonate is even more efficient than the calcium salt, but is not always equal to the bicarbonate. At Emden, in 1897, treatment with the latter was successful after the carbonate had failed.

Inasmuch as the influences for and against corrosion are numerous and conflicting, the surest method of determining whether a given water will attack lead is to ascertain the truth by actual experiment.

Regardless of the character of a water itself, it may be said that its action is greater if the lead is in contact with other metals, so that a galvanic couple is formed. Such may occur, for instance, when a tin-lined lead pipe is bent so that the lining is fractured. Then the two metals being in contact with each other in a more or less saline liquid, the lead, being the more easily oxidized, is dissolved. Again, the tin lining may develop weak spots which may become corroded, and as soon as the lead casing is reached, galvanic action becomes established. Lead pipe containing a small percentage of tin will yield more lead to water than will ordinary lead pipe, especially if free carbon dioxide is present.

A new lead surface will yield more than an old one, as is shown by Professor Mason, who found that the same water, stored for three and a half months in contact with new and old lead, yielded 58.10 and 3.65 parts per 1,000,000, respectively.

Hot water is more corrosive than cold; and in the case of either, the solvent power is increased by pressure.

The result of the continuous ingestion of minute amounts of lead may be *nil* or the production of more or less marked manifestations of chronic lead-poisoning. From the fact that lead-pipe is in very general use for house-mains and distributing pipes, and that chronic lead-poisoning is, comparatively speaking, a not very common trouble, it seems reasonable to conclude that with the great majority of persons the metal is eliminated with sufficient rapidity to prevent accumulation and cumulative action. In Massachusetts, notwithstanding the enormous use of lead for service-pipes, in but few communities has there been any considerable amount of lead-poisoning reported, and in all of these the water-supply comes from driven wells.

Occasionally, fatal lead-poisoning is caused. In one such case, reported by V. Schneider,[1] the water was very soft (hardness 1.40) and contained 0.95 milligram of lead per liter. After three months' use of the water, a girl of seventeen died with all the characteristic symptoms of lead-poisoning. Analysis of the organs yielded lead to the extent of 7.5 milligrams from the œsophagus, stomach, and duodenum, and 24.7 milligrams from the kidneys, liver, and spleen.

Action on Iron.—Corrosion of iron is favored by the presence of nitrates, nitrites, ammonium compounds, mineral and organic acids, chloride of magnesium, oxygen, and carbon dioxide. The latter is especially active, as has been shown by Professor Leffmann and by R. Petit. The latter,[2] investigating the cause of the destructive action of water rich in this gas and poor in lime, placed a certain amount of iron filings in each of three vessels, one of which contained ordinary water, the second contained water through which a stream of carbon dioxide was conducted for several minutes, and the third was filled with water to which sufficient caustic lime had been added to bind the dissolved carbon dioxide and to give an alkaline reaction to phenolphthalein. After a time, the iron in each specimen was determined, with the following results, which prove the great influence of the gas:

1. 3.15 milligrams per liter.
2. 200.60 miligrams per liter.
3. Only traces.

Both cast-iron and wrought-iron pipes may be acted upon rapidly unless their inner surfaces are covered by some protective coating, such as asphaltum, and even then at the joints where the protecting surface is not continuous or becomes detached. Some surface-waters form a protective layer of vegetable matter on the surface of the pipe, and this is far more efficient than artificial applications, and possesses the additional merit of imparting no unpleasant taste.

Action on Zinc.—On account of the action of water on plain iron pipes, pipes of galvanized iron, that is, iron coated within and without with metallic zinc, have been recommended. This lining, however, is

[1] Gesundheits-Ingenieur, March 31, 1897.
[2] Comptes rendus, 1896, p. 1278.

corroded very easily, especially if the water contains oxygen, carbon dioxide, ammonia, or nitrates, and the water is made milky by the oxide and carbonate in suspension.

Whether or not the zinc compounds occurring in water can be productive of harm, is a point on which authorities differ. But at least it must be admitted that they may cause chronic and obstinate constipation, even when present only in small amounts, and that zinc is not a cumulative poison. Dr. John C. Thresh[1] mentions a case of obstinate constipation in a child, due to the use of drinking-water which passed through a half mile of galvanized pipe. Relief followed discontinuance of the supply.

Gimlette[2] has reported an extensive outbreak of poisoning attributed to water stored in galvanized iron tanks. Of 56 consumers, 43 were attacked with gastro-intestinal troubles, the symptoms presented being colic, diarrhœa with consequent anæmia and emaciation, and a spurious kind of dysentery. Analysis of the water revealed large amounts of zinc.

Analysis of water drawn from galvanized pipes often has revealed very large amounts of zinc. Messrs. J. A. and E. W. Voelcker[3] record an interesting case in which the hot-water pipes of a house supplied by water piped a half mile through galvanized iron, were blocked completely by a deposit of zinc. The water was very pure and soft, and contained but 6 grains of total solids per gallon. The deposit contained 64.32 per cent. of basic carbonate and 21.96 per cent. of oxide of zinc.

Zinc is sometimes a normal constituent of water. Myelius[4] found about 0.5 grain per gallon in the water supply of Tutendorf, and Carl T. Mörner[5] has reported the presence of 0.015 part of zinc carbonate per 1,000,000 in the water of a well near Upsala. This well, which was about fifteen feet deep, had been in use for more than a year. The water was submitted for analysis solely on account of its peculiar taste, and beyond the fact that it yielded zinc, the source of which could not be determined, the results of the analysis were very favorable. No unpleasant effects had been noted among those who used the water. Two springs in Missouri, according to Hillebrand,[6] yield much larger amounts. In both, the zinc exists in the form of sulphate. The yield amounts to 120.5 and 132.4 parts per 1,00,000, respectively.

Action on Tin.—It is supposed commonly that tin is unaffected by water, but such is far from being the case. Tin is attacked by water to a considerable extent, although not so readily as the other metals mentioned; but the compounds formed are, so far as we know, incapable of causing the slightest injury to the system, and this metal

[1] Water and Water Supplies, London, 1896.
[2] British Medical Journal, Sept. 7, 1901.
[3] The Analyst, July, 1896.
[4] Ibidem, IV., p. 51.
[5] Upsala Läkareförenings Förhandlingar, 1898, Vol. III.
[6] United States Geological Survey, Bulletin No. 13.

is recommended highly as a lining for iron pipes. Its cost alone prevents it from supplanting lead for house-mains and distributing pipes.

Water and Disease.

The use of impure water for drinking and other domestic purposes may be a direct cause of disease, and such water is supposed also to act upon the system in such a way as to lower the resistance of the body to the action of infectious matters; but it should be borne in mind that the nature of the polluting material is of far greater importance than its mere amount. To maintain that water containing any considerable amount of organic matter, regardless of its character and source, will tend inevitably to produce a general impairment of health, is as great an error as to underrate the danger possible to arise from a small amount of specific contamination. It is quite as improbable, for instance, that the amount of dissolved vegetable matter necessary to yield albuminoid ammonia in what may be designated "considerable" amount can do any great injury, even when constantly ingested, as that an infusion of tea, which, by the same process of analysis, would yield results which would be startling in comparison, could of itself conduce to the development of an infectious disease.

Alarmists may reject as unsuitable for household purposes a water containing an amount of vegetable matter sufficient to give a yellow-brown color, and accept as sufficiently pure another containing less organic matter and less mineral matter, but with it the micro-organisms of infectious disease. They go to the extreme of saying that organic matter in solution must "lower the tone," and should, therefore, be avoided, and if asked why this is so, fall back on "general principles" and "common sense," upon which so much illogical, unexplainable theory is based. As a matter of fact, we know that water which is in a sense impure, but not specifically polluted, may be used year in and year out without injury. We know, farther, that water containing much less organic matter, but infected with bacteria of certain kinds, is likely to cause disease in at least a proportion of those who use it once, occasionally, or habitually. We know also that a water once specifically polluted may, under similar conditions, be polluted again, and in the interval may be of good quality.

We know that water containing large amounts of dissolved vegetable matter in process of decomposition or of a definitely poisonous character may produce disturbances of a very serious nature; that an abundance of minute water plants, as algæ, and animal organisms, as infusoria, may produce ill effects; that decomposing animal matters sometimes yield toxic substances of great potency, and that excessive mineral matter in suspension or solution is not without its deleterious effects.

Therefore, it may be laid down as a general rule, regardless of the fact that all impurities do not necessarily breed disease or undermine the health, that all water containing or likely to contain domestic

sewage, abundant growths of minute vegetable and animal organisms, decomposing matter of animal origin, dissolved vegetable matter of an inherently toxic nature or undergoing decomposition, or excessive amounts of mineral matter, should not be accepted as fit for human consumption. Especially should we bear in mind that polluted water which is quite free from disease organisms and toxic matters to-day may contain them in abundance to-morrow.

Disorders Connected with Mineral Matter.—It is noticed very commonly that when one changes suddenly from the use of a soft water to another that is quite hard, there follows a temporary disturbance of the functions of the digestive apparatus. The most marked effect is usually constipation with occasional diarrhœa. Loss of appetite and slight nausea are not uncommon. The effects are due to the influence of the salts causing permanent hardness. Change from hard to soft water is quite as likely to cause unacccustomed looseness of the bowels from the withdrawal of this influence on the intestinal secretions. Just how much of any one of these salts may be said to be distinctly injurious to health is a matter of doubt, but commonly from 10 to 15 parts in 100,000 of water are regarded as undesirable. It has been asserted that the use of hard water is one of the chief causes of stone in the bladder, but such a connection is extremely improbable. How the use of carbonate and sulphate of calcium can bring about a deposit of uric acid, or of oxalate of calcium, or of phosphates in the bladder, can hardly be explained. The fact also that stone is very common in some districts where water is soft, and rare in some others where it is hard, suggests that the cause is to be looked for rather in the individual himself—his food, his metabolism, his habits of life, and, perhaps, hereditary predisposition.

Suspended mineral matter, as clay and marl, will often cause diarrhœa in persons not habituated to its ingestion, and not infrequently in those who are.

The disease most commonly connected with mineral matters in water is goitre. That this disease may be produced by drinking-water, can hardly be doubted, for it is a well-known fact that in Switzerland and France, for instance, there are wells which yield waters which are used successfully for the intentional production of the disease, with the view to escape compulsory military service. The enlargement is not necessarily a permanent disfigurement; disuse of the water may be followed by disappearance of the swelling, but oftentimes the disease thus intentionally acquired persists.

The exciting cause has been attributed to the presence or absence of certain mineral substances, but the wide variety of the supposed agents is, of itself, strong evidence of the poor foundation upon which the mineral matter theory rests. It is noticed, for instance, that in some districts where the disease is especially prevalent, the soil is largely magnesian limestone, and that, as might be supposed, the ground-water is rich in lime and magnesium salts. Therefore, it is reasoned, magnesian limestone must be the cause; but there are many such districts

where goitre is unknown. More than that, the disease is endemic in some quarters where the water is soft and almost free from lime and magnesium salts. Again, it has been attributed to the presence of certain salts of iron, but this theory also cannot bear the test, for these may be present where no goitre is seen, and may be absent where the disease prevails. Absence of iodine is another explanation based on nothing worthy of credence.

The most probable cause is now believed by some to be an organism which flourishes in the water. The first to promulgate this theory were Italian observers, who, in 1890, reported facts of interest bearing on the question, since which time, other observers, particularly in India, have contributed farther evidence of its probable truth.

The most striking facts have been presented by Surgeon-Lieutenant E. E. Walters,[1] whose observations were pursued in a district in India 2,000 feet above sea-level, with extremely porous soil and a water supply containing but slight amounts of organic and mineral matter, and but minute traces of iron. The inhabitants, who live under the same climatic conditions, but with different occupations, may be divided into two classes: the native Bhutias and the Sepoy troops from the northwest provinces. The former are carriers and coolies; they are omnivorous, but, by reason of poverty, mostly vegetarians. Their chief diseases are goitre, syphilis, and malaria. The temporary inhabitants, the Sepoys, are all vegetarians, and are a healthy lot, practically free from syphilis, and living under excellent hygienic conditions. They had been in the district twenty months. Examination of 169 Bhutias showed that more than 75 per cent. had goitre; nearly 70 per cent. of those over twelve years of age were afflicted. Of 380 Sepoys examined, 54 per cent. had goitre. The Bhutias say that their goitres increase during the rainy season, and this is borne out by the out-patient register and regimental admission book for 1895. All the British officers, too, had suffered from enlarged thyroids during the preceding rainy season. Their drinking-water was passed through a Pasteur filter; all other water used was taken as tea or soda. Taking up the several conditions which have been alleged as the cause of the process, he shows them to be not at fault in this particular district. Iron was present in the water in only minute quantities, and the highest degree of permanent hardness was but 3.5. As to lime as a cause, it appears that many of the Bhutias without goitres are great eaters of lime, while of the Sepoys, who never touch it, more than 50 per cent. developed goitres within twenty months after arrival. The theory that the disease is due to carrying heavy loads up and down hills, might satisfy in the case of the Bhutias, but not in that of the Sepoys, who, though not carriers, yet have goitre. Farther, as to age, it appears that 55 per cent. of the children under twelve had no goitres after living there all their lives, or about the same percentage as developed them among the Sepoys after a visit of only twenty months. He believes the disease to be due to an organism of the amœba type, with a selective power against the

[1] British Medical Journal, September 11, 1897.

thyroid or its secretion. For a time the system opposes it, and sometimes successfully; but when the cause overpowers the phagocytic resources of the system, the thyroid enlarges in the effort to combat the poison. Under thyroid feeding (two 5-grain tabloids daily) the records show a weekly diminution of a quarter to half an inch in the circumference of the Sepoys' necks, but when the treatment ceases, the gland again increases in size. That is to say, additional resisting power is conferred by thyroid tabloids, which keep the poison in check and allow the gland to recover its normal size; but on withdrawing the accessory agent, there is diminished resistance and then again an increase in size.

Disorders Connected with Organic Pollution.—Ordinary vegetable matter in suspension and abundant growths of algæ and other water plants sometimes cause diarrhœal troubles, but they do not cause specific disease. Peaty matters in solution have now and then appeared to be connected with intestinal derangement, but we have no absolute knowledge that they actually have been or can be a cause of such trouble.

We know three epidemic diseases which we may say with certainty can be carried by water. These are: cholera, typhoid fever, and dysentery, but it is said commonly that water is a great factor in the spread of diphtheria, yellow fever, and malaria. In the case of diphtheria, the weight of evidence is certainly against its being a water-borne disease. There is some evidence of its spread through the use of a common water supply, but in these cases there is usually a common drinking vessel, and probably a preëxisting case of the disease among the drinkers. The diphtheria organism cannot long survive in water which is not very extensively polluted.

As to yellow fever, there is no evidence whatever of value, but in the older literature of hygiene many outbreaks attributed to polluted water are recorded. In the light of our present knowledge, these instances have, naturally, no standing, but in justice to those who recorded them it must be said that, before the discovery that the disease was mosquito-borne, the evidence presented seemed to be uncontrovertible. For example, outbreaks occurring at sea aboard ships that recently had been in infected ports, where the water-casks had been refilled, could not be attributed to telluric influences, and the replenished water-supply offered the only explanation.

As with yellow fever, so with malaria, abundant evidence of connection with water as a cause has been recorded, although the fact has long been known that water from malarial districts may be used by communities at a distance without harm, as is the case with the city of Rome.

One of the best cases which have been accepted as proof of transmission by water is that reported by Laveran, who failed, however, to furnish certain facts which our present knowledge would require. A detachment of soldiers drank at a certain well, and then enjoyed a hearty meal; another detachment ate first, and later drank from the same well. Of the former, all became sick with malaria; of the latter,

not one was affected. The difference in the results was thought to be due to the fact that those who escaped took no water until the gastric juice was secreted in the process of digestion. Quite a number of cases are recorded in which men on shipboard have used the water of certain casks which others had declined, the former becoming sick with malaria, and the latter escaping.

There is evidence that certain animal diseases may be spread by water containing the specific organism. Hog cholera and anthrax have certainly been spread by water into which the bodies of those that had died of these diseases had been thrown, and glanders may be spread from horse to horse by the use of a common drinking trough.

The diseases of greatest interest in connection with drinking-water are two which we know can be spread by infected water—cholera and typhoid fever. The first-mentioned happens, with us, to be one of minor interest, inasmuch as it is a most uncommon visitor; the other, however, is always with us, and we have, therefore, constant opportunity for observation of the influence of polluted water in its causation.

The strongest proof of the value and efficiency of the purification of water by filtration through sand is the drop which occurs in the mortality from typhoid fever when a community abandons the use of untreated polluted water, and adopts this method of improving the quality without changing the source of supply. The city of Lawrence, Massachusetts, for example, prior to and including part of the year 1893, used the unfiltered water of the Merrimac River, into which is poured the sewage of a succession of large cities and towns having an aggregate population of several hundred thousands. In the year mentioned, the process of filtration was adopted, and good results were almost immediately evident. Following are the death-rates from typhoid fever per 10,000 of population for the four years immediately preceding and for the same period following the change:

Preceding change.	Year of change.	Following change.
1889 . . . 12.7	1893 . . . 8.0	1894 . . . 4.7
1890 . . . 13.4		1895 . . . 3.1
1891 . . . 11.9		1896 . . . 1.9
1892 . . . 10.5		1897 . . . 1.6

It is but fair to add that about half the deaths from the disease in 1894 and 1895 were of persons who persisted in drinking unfiltered water directly from the canals.

The city of Hamburg adopted filtration in May, 1893, after a most devastating epidemic of cholera in the preceding year. Typhoid fever had always claimed a very large number of victims annually, and during the four years 1890–1893, the death-rate from the disease was 2.6 per 10,000; but in the next two (1894–1895), it fell to 0.75.

Comparison of typhoid death-rates of cities using polluted waters

with those of others using pure or purified waters is most convincing both of the efficiency of filtration and of the disastrous results of neglecting to protect the public from the dangers of impure supplies. The cities of Chicago and Berlin may well be selected for comparison, having approximately the same number of inhabitants. Chicago takes its water from Lake Michigan, into which vast volumes of sewage are poured at various points, and uses it without purification. Berlin is supplied by two lakes, Tegel and Müggel, which are protected so far as possible from pollution, but, nevertheless, every gallon used is filtered. During the years 1890–1894, the death-rates from this one disease averaged 84 per 100,000 at Chicago, and but 8, or less than one-tenth as high, at Berlin. Between 1889 and 1893, Chicago suffered unusually from typhoid, and in 1891 the typhoid mortality reached 159.7 per 100,000. At this time, the intake was situated but a few hundred feet from the shore, and, in consequence of the ravages of the disease, a tunnel was built, extending the intake four miles into the lake. The result of this extension was an immediate marked fall in the number of cases, but nothing comparable to what might reasonably be expected had the water been subjected to filtration.

The experience of Philadelphia within recent years furnishes a most instructive example of the danger of using polluted water. During the first six months of the year 1899, in a population of over a million, 7038 cases of typhoid fever, with 800 deaths, were recorded. During the first five weeks of 1902, 510 cases occurred, with 49 deaths. Between January 1 and April 11, 1904, in a population of about 1,300,000, there occurred nearly 2500 cases; and of these, no fewer than 389 were reported in a single week, this number being the largest ever reported in any week in the history of the city. In that part of the city to which the new supply of filtered water was furnished, there was an almost immediate fall in the typhoid rate, the immediate neighborhood not so supplied continuing to maintain a much higher rate.

Typhoid Infection of Water Supplies.—Typhoid infection of a water supply may be direct or indirect. Direct infection occurs through the entrance of ordinary sewage containing the essential organism, or of fæces or urine discharged along the banks of a river or lake, for example, by persons suffering with or convalescent from the disease. Indirect infection occurs from discharges deposited in or upon the soil, and thence washed by rain into bodies of water or downward into wells. Ordinary sewage pollution is not sufficient to bring about an outbreak of the disease, nor will specific pollution necessarily always be followed by the occurrence of cases. The specific organism has only a limited tenure of life, and, in the absence of conditions favorable to its existence, it may perish before it reaches the consumer. Moreover, the number present may be very small and the effects produced so slight as to occasion little notice. It is to be borne in mind that not every mouthful of a polluted supply contains the organism, and that not every person to whose system it gains access must necessarily come down with the disease.

Until quite recently, it has been supposed that the infecting organisms had their origin only in the fæces of preëxisting cases; but it is now known that this is far from being the case, and that they exist in the fæcal discharges during only the early stages of the disease, or up to the twentieth day or, perhaps, even somewhat later. Petruschky[1] has shown that the urine may contain millions of living bacilli in each cubic centimeter, and that they may be found for many weeks, and even after convalescence is well established. They may appear as early as the fifteenth day, when, perhaps, they are no longer demonstrable in the fæces. Dr. Mark W. Richardson[2] found them in very large numbers and in practically pure culture in the urine of nine out of thirty-eight patients. They appeared late in the course of the disease, and continued to be eliminated in several of the cases after discharge from the hospital. These observations of Petruschky and Richardson have been confirmed by other bacteriologists. It appears, then, that an apparently well person is capable of infecting a water supply to a greater extent and with less optical evidence, or none at all, by a discharge of urine into a water course than an evidently sick one by a deposit of his fæces into it or upon its banks.

Whatever the mode of infection of a public water supply, the results, if any, are seen in an increase in the number of cases ordinarily occurring in the community supplied, and, except in those instances where the disease is spread by infected shellfish or other foods, any considerable augmentation of cases points unmistakably to the consumption of polluted water, even though the system of filtration is followed. In the latter instance, investigation almost certainly will show some defect in the filters, or that their capacity has been overtaxed. Even after subsidence of the outbreak, the disease may continue to be more prevalent than usual for some little time, especially in the absence of a proper system of sewerage.

Influence of Introduction of Public Water Supplies on Typhoid Rates.—Contrary to what might be expected, the highest death-rates from typhoid fever in thickly settled countries are, generally speaking, not in the crowded cities, but in the towns which have no public water supplies. In Massachusetts, for example, the 5 towns highest in this respect had, during the eighteen years prior to 1890, an average typhoid death-rate of 12.82 per 10,000 of population, while the average of the five highest rates for cities with public supplies was but 7.65, and of all the cities of the Commonwealth only 4.62. In the town with the highest mortality, Ware, the average for fifteen years prior to 1866 was 16.5 in 10,000; in that year a public supply was introduced, and at the expiration of four years the mortality had diminished 60 per cent.

In 1870, only 20 cities and towns in Massachusetts had modern public supplies; at the end of 1896, all of the 32 cities and 127 of the 322 towns, comprising 89.8 per cent. of the entire population, were

[1] Centralblatt für Bakteriologie und Parasitenkunde, 1898, XXIII., No. 14.
[2] Journal of Experimental Medicine, May, 1898.

thus provided, and but 3 towns with populations exceeding 3500 had none; at the end of 1904, but 8 per cent. of the entire population of 2,805,000 were without public supplies, and this was made up very largely of the very small towns with scattered inhabitants, where the introduction of public works would be beyond the financial possibilities. As a result of this very general introduction of a common supply in place of that derived from individual wells, largely of the open variety and situated in close proximity to sources of pollution, a decided decline in typhoid fever has been noticed. This result is by no means peculiar to Massachusetts, but is found to be the consequence wherever the selection of the source is made with judicious care and measures are taken to protect it from avoidable pollution. It is not to be supposed, however, that the mere introduction of a common supply without the observance of this necessary precaution will best serve the interests of the public health. In the following table, compiled by Mr. Hiram F. Mills,[1] is shown the change in the typhoid death-rates per 10,000 in each of the cities of Massachusetts which introduced water within the years 1869 to 1877:

Cities.	Yearly number of deaths from typhoid fever per 10,000, 1859 to 1868.	Date of introduction of water supply.	Yearly number of deaths from typhoid fever per 10,000, 1878 to 1889.	Deaths in second period per hundred of those in first.
Holyoke	6.73	1873	8.93	133
Lawrence	8.34	1875	8.33	100
Lowell	6.16	1872	7.63	124
Fall River	7.78	1874	6.32	81
Springfield	9.67	1875	5.29	55
Taunton	6.12	1876	5.02	82
Northampton	10.98	1871	4.04	37
Lynn	9.06	1871	3.87	43
New Bedford	7.77	1869	3.80	49
Newton	6.57	1876	3.65	56
Malden	8.04	1870	3.54	44
Fitchburg	10.59	1872	3.16	30
Woburn	8.29	1873	2.95	36
Somerville	4.28	1867	2.95	69
Chelsea	5.97	1867	2.89	48
Waltham	8.12	1873	2.42	30

It will be noticed that of these sixteen cities there were three which showed no improvement, and two of these were worse off than before. The reason for this is clear. All three are manufacturing cities, situated on rivers polluted by sewage. At Holyoke, while the public supply is but slightly liable to contamination, the operatives in the factories used water from two other sources, subject to gross pollution; namely, from the canals, the entrance of one of which is situated close to the outlet of one of the main sewers of the city, and from wells indirectly supplied by the canals. Comparison of the death-rates from typhoid fever among those of different occupations, brought out the fact that the operatives in the mills which used canal water suffered

[1] 22d Annual Report of the State Board of Health of Massachusetts, 1890, p, 534.

from the disease three times as much pro rata as all other persons. Lowell and Lawrence, at the time mentioned, were using the polluted water of the Merrimac River. Lowell took its supply fourteen miles below the point of entrance of the sewage of Nashua, N. H., and consumed it without treatment. Lawrence drew upon the same supply, after its enrichment by the sewage of Lowell, at a point but nine miles below the outfall of the latter's sewage. In 1891, Lowell suffered unusually from typhoid fever by reason of the additional contamination by fæces of typhoid patients discharged into Stony Brook, a small tributary of the Merrimac, only three miles above the intake of the water-works.

The conditions of all three places have since been changed. At Holyoke, warnings were posted for the benefit of the operatives; Lowell abandoned the river in favor of ground-water in 1893, and in the same year Lawrence instituted filtration. In all of the three cities the expected happened; namely, a marked diminution in the death-rate.

Examination of the above table reveals the fact that in the majority of the sixteen cities the reduction in the typhoid death-rate was most pronounced. In some of them, the diminution has proceeded to a much greater extent than is shown here. In 1896, three cities with an aggregate population of 70,000 showed less than 1 death per 10,000 from this disease, and in one of them, Woburn, there was none at all.

Examples of Typhoid Fever Epidemics and of Limited Outbreaks Traced to Infected Water.—For the purpose of illustrating to what an extent specifically polluted water can, under favorable conditions, bring about a sudden outbreak or explosion, the following cases have been selected from the many which are to be found in the literature of hygiene.

Epidemic at Lausen, Switzerland.—This best known and most often quoted of epidemics of typhoid fever was practically the first one of any considerable extent to be traced undisputably to the use of specifically polluted water, although many outbreaks, large and small, had been ascribed to the use of water "containing considerable organic matter," and only supposedly infected.

Up to 1872, this village of 780 inhabitants had not been visited by typhoid fever, even in sporadic cases, for sixty years. On August 7th, with no previous warning, ten persons were seized, and during the next ten days nearly sixty more. The number of cases increased from day to day until 130 persons, or one-sixth of the entire population, had been seized. So large a percentage of involvement pointed to some common cause, and the immunity enjoyed by the inmates of a group of houses not connected with the public water supply directed attention to the latter, which was derived from a spring at the foot of a ridge about 300 feet high, between the village and the Führler valley. In this valley, at a point between one and two miles distant from Lausen, was an isolated farm where dwelt a man who, on June 10th, shortly after his return from a visit, was taken sick

with typhoid fever. Before the end of July, three cases more developed in the same house. The discharges of all four were thrown into a brook in which the family washing was done, and which served to irrigate the meadows below. Whenever it was dammed up for this purpose, the volume of the water supply beyond the ridge was noticeably increased. Between July 15th and the end of the month, the meadows had been submerged by this process, and in three weeks from the beginning of the operation, the explosion occurred in Lausen.

The sequence of events was, then, the appearance of the initial case on June 10th, and of three more in the same house before the end of July, the daily pollution of the water of the brook, the damming of the brook in the middle of July, and the appearance of the first cases in Lausen on August 7th. Everything pointed to direct connection between the impounded water and the spring a mile or more distant on the other side of the ridge, and its existence was established by dumping about a ton of salt into the brook and noting its speedy appearance in the Lausen spring. As a very large amount of flour, deposited at the same place, gave no evidence of its appearance, even in traces, it was proved that the water passed through a coarse filtering medium rather than through an open underground passage.

The Plymouth, Pa., Epidemic.—The town of Plymouth, Pennsylvania, had, at the time of the epidemic in 1885, a population of about 8,000 people. The general water supply was derived from a mountain brook, which was dammed at intervals so as to form a series of impounding reservoirs, but a large part of the population was supplied by individual wells. A citizen who spent the Christmas holidays at Philadelphia returned in January to his home, ill with typhoid fever, and had a very protracted sickness. During the entire period, his excreta, which were in no way disinfected, were thrown upon the snow and ice on a slope not forty feet away from the brook, at a point midway between two of the dams. At this time the brook was frozen over, and it remained so until the approach of spring. During the last third of the month of March, there was a sudden period of warmth, and the snow and ice began to melt. Shortly afterward, the warm spring rains began, and the ice and snow and frozen excreta upon the slope were melted, and the entire accumulation was washed into the brook, and thence into the water mains. Within three weeks thereafter, cases of typhoid fever by the score made their appearance throughout the town. On some days, more than a hundred new cases were reported, and on one, the number reached nearly two hundred. The total number of seizures has variously been stated, the lowest estimate being 1,000 and the highest 1,500. The number of deaths was not less than 114, and has been placed as high as 150.

It was discovered that the epidemic was limited practically to those whose houses were supplied by the town mains, and to those who, while supplied at home by wells, drank of the public supply while absent from home during working hours. This distribution was par-

ticularly emphasized in one street, where the houses on one side all had one or more cases, while those on the other had none at all. The former were supplied by the town mains, and the latter depended upon wells.

Outbreak at Uvernet.—A somewhat similar outbreak, on a much smaller scale, is reported by Dr. Dupard[1] as occurring at a small village in the Alps, the details of which are as follows: In October, 1898, a detachment of 157 infantry soldiers were quartered in four houses in the village, each house sheltering approximately a fourth of the men. In one, where 37 were quartered, there appeared within a few weeks 22 cases of typhoid fever, 6 of which terminated fatally. At the time of seizure, there were no other cases in the village, nor did any appear in any other house than this one. Investigation revealed the fact that, a few days before the arrival of the troops, a child of ten years had been taken ill with the disease in another house situated on higher ground, about 400 feet away from the house in question. Where the child lay ill, there was no privy, and his excreta were thrown upon the ground in a neighboring field. His soiled clothes were washed in the spring nearby. At the time of the soldiers' arrival, a number of heavy rains occurred, by which the surface impurities of the soil in the neighborhood of the house where the child lived would, by reason of the inclination of the ground, be washed toward the house occupied by the soldiers. This was supplied by water from a small stream through a rude main constructed of worm-eaten hollow logs laid in a shallow depression in the surface of the soil. There could be no question of the probability of contamination of this supply by the fæcal discharges thrown upon the ground in the vicinity, and in the absence of any other cases and with the high percentage of seizures in the one house, no other explanation appears to be possible.

Epidemic at Ashland, Wisconsin, in 1893–94.—This outbreak is one of peculiar interest, in that, in addition to serving as an excellent illustration of the danger of using the same body of water as a place for the disposal of sewage and as a source of drinking-water, it was made the basis of an action at law, which established the liability of water companies and municipalities in case of sickness and death caused by the distribution and use of infected water.

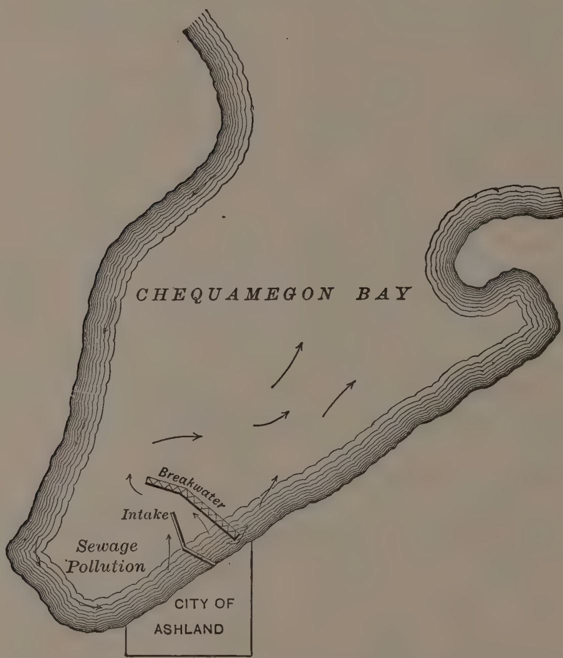
The city's supply is derived from an arm of Lake Superior, Chequamegon Bay, upon which the city is situated. This bay, which is about twelve miles long, and of an average width of five, varies from eight to thirty-six feet in depth. North of the city, and extending outward in a northwestwardly direction, is a breakwater constructed for the protection of the harbor against northerly gales; and between it and the city the mouth of the water intake is located about a mile from the shore. (See Fig. 35.) The sewage of the city is discharged further to the west and south. The currents in the bay follow the course indicated by the arrows in the figure, and carry the sewage toward the breakwater and over the mouth of the intake. This con-

[1] Lyon médical, Jan. 1, 1899, p. 5.

dition of affairs was brought to the attention of the company by the health boards of the city and state repeatedly, but without results. That the water was polluted, was evident on mere ocular inspection, for it was often cloudy or markedly turbulent. During the winter of 1893–94, typhoid fever made its appearance in the city, and from the initial cases a disastrous epidemic developed, which led to the establishment of a model filtering-plant.

The action at law referred to above, was brought by the widow of one of the victims. In evidence, it was shown that he lived continuously in Ashland, and drank no water other than that supplied by the

FIG. 35.



Conditions obtaining at Ashland, Wis., prior to the epidemic of 1893-94.

water company; that previous to his seizure the disease had prevailed in the city, and that the discharges from the antecedent cases had passed into the waters of the bay by way of the city sewers. The court found for the plaintiff in the sum of $5,000.

Epidemic at Luneburg in 1895.—The ancient town of Lüneburg, with a population of 22,000, has a system of sewers which empty at two points into the small River Ilmenau. The public water supply is in the hands of a number of separate corporations, which had their origin in mediæval guilds; and as the two principal ones supply the same parts of the town, it happens that their mains run through the same streets, and that not alone adjoining houses, but even different stories

of the same building are supplied by either one according to circumstances. The Raths Company furnishes a ground-water which is perfectly good, except for its rather high content of iron, which sometimes has caused more or less trouble. The other large corporation, known as the Abts Company, obtains its water from the Ilmenau, usually at a point above the town; but between July 15th and 20th, it drew it from a place in the middle of the town, opposite the pumping-station, where the water was extremely impure. Previous to these dates, typhoid fever, which was always present in some amount in the town, had begun to appear to an unusual extent; and in the first half of August, there was a sudden and remarkable increase in the number of cases. On the termination of the outbreak, 205 cases had been reported, 169, or 82.44 per cent., of which were among families supplied with the water of the river.

It was proved that, for a period of some days, which included the dates above mentioned, the diarrhœic discharges of a young girl, sick with typhoid fever, were thrown, without being disinfected, into the river at a point about 300 feet above the intake and on the same side. In addition to this one source of the causative agent which produced such a sudden rise in the curve, it was known that the river had been polluted by the discharges of another patient in May, and that the epidemic had its real beginning in June. It is conceivable that in a town where the house supplies are so complicated that different stories have different kinds of water, a fair percentage of the victims of an epidemic may acquire the disease through neighborhood visiting, though their own domestic supply is of the proper quality. In this whole outbreak, only 17.56 per cent. of the cases were among people whose premises were supplied by the other companies.

Epidemic at Zehdenick in 1897.—This was a local outbreak traced to the contamination of a well by the discharges of a child sick with typhoid fever. The water was used by the inmates of the houses in the immediate vicinity, and the disease was limited to them alone. Of 303 persons making up the 29 households of the neighborhood, 94, or nearly a third, were seized within a short period, while not another case was known in the town. The inmates of nine houses within the infected area, who obtained their water from another source, were untouched.

Limited Outbreak Among Soldiers.—An infantry regiment, returning from the autumn manœuvres, passed through a small village where typhoid fever existed, and halted for water. Two days afterward, 3 men were seized with great suddenness, and within two weeks, 36 men were down with the disease. They had been exposed to no other source of infection, and other troops who passed through the same village without stopping for water were unaffected. Knowing the day when the infection occurred, and since in every case the onset was marked by very acute symptoms, Dr. Emil Jauchen[1] was able to determine the exact period of incubation: 3 were seized on the second

[1] Wiener klinische Wochenschrift, July 7, 1898.

day, 7 on the third, 6 on the fourth, 4 on the fifth, 4 on the sixth, 5 on the seventh, and 7 between the ninth and the fourteenth. The short periods are explainable by the fact that the men were in a state of exhaustion at the time of drinking, and all took copious draughts.

Epidemic at Butler, Pa., in 1903.—Butler, Pennsylvania, is a thriving city of about 16,000 inhabitants, supplied with water from three sources, two of which are situated at different points on Connoquenessing Creek, and the third is an impounding reservoir on Thorn Run, which is the chief tributary of the creek. On August 28, 1903, the dam at Boydstown, some seven or eight miles above Butler, was carried away, and the main source of supply being thus lost, the water company was obliged to use water from the Thorn Run reservoir and to pump directly from the creek at the pumping-station. Before distribution, the water was treated in a rapid mechanical filter, from which it was sent to the city reservoir. On October 21, the filter plant was shut down for repairs, and during the next ten days the city was supplied with unfiltered water, taken directly from the creek at the pumping-station. On November 2, an epidemic of typhoid fever began, and so rapidly did it spread that, by December 17, no less than 8 per cent. of the population (1270 cases) had been attacked, and 56 persons had died. That the epidemic was due to the water-supply was emphasized by the fact that a portion of the city, known as Springdale, with a population of about 2500, not provided with city water, but supplied by deep wells, was almost wholly exempt, there being but 2 cases within the district. The source of the infection was not far to seek. Throughout the summer and autumn, fairly numerous cases of typhoid fever had occurred at various points on the watershed, and there was ample opportunity for the dejecta to be carried into the numerous small tributaries and thence into the creek. In one house, for example, provided with a privy overhanging a small stream which empties into the creek within a short distance from the pumping-station, there occurred, subsequent to October 1, no fewer than 5 cases of the disease. In another house near Thorn Run dam there was a case about the middle of August, and this was followed by 3 others.

Epidemic at Ithaca, N. Y., in 1903.—At the time of this outbreak, Ithaca, New York, the seat of Cornell University, was a city of about 13,000 people, with an additional student population of nearly 3000. Its location and surroundings are, in general, unusually favorable to health; in 1900, the death-rate from all causes was but 16.3 per thousand. The public water-supply was furnished by three creeks, which flow into Lake Cayuga, but many of the population depended upon private wells, of which there are about 1500 within the corporate limits. The water company which supplied the city proper derived its water from Six-mile Creek and Buttermilk Creek; the University was supplied by Fall Creek, under its own management. The watersheds of these three creeks are not large and they are more or less thickly populated. Abundant opportunities exist for direct infection of all three creeks,

privies and outhouses being situated in many instances within a few feet of the banks. On Six-mile Creek alone, according to Dr. George A. Soper, the probable sources of infection at the time of the epidemic numbered a hundred or more. The conditions existing within the watershed of Buttermilk Creek are said to have been equally bad, while those along Fall Creek were even worse, although, as will be seen, this source of supply appears not to have been specifically polluted. In addition to the usual sources of contamination of the water of Six-mile Creek, there were employed during November and part of December, 1902, about 60 laborers in the construction of a dam, but careful inquiry failed to show the existence of any sickness among them during the period of their employment.

The public supply had long been viewed with suspicion, and many of the population who used it were accustomed to boil the water before drinking it. Diarrhœal disturbances and a mild form of typhoid fever, known as "Ithaca fever," had for many years been very common. During January and February, 1902, it is said that there were nearly 100 cases of typhoid fever in the city. During the spring of that year, repeated bacteriological and chemical analyses of the water of Six-mile Creek, taken from the service pipes, yielded results which indicated dangerous pollution, and the people were warned through the newspapers against its use without previous boiling. On January 1, 1903, several cases of undoubted typhoid fever were reported, and thereafter the number reported daily increased to such an extent that, on February 2, there were no fewer than 237 cases under treatment. By the middle of March nearly 800 cases had been reported, but the actual number of persons affected was undoubtedly much larger. It is asserted that more than 1000 cases existed at that time, and that during the first six months of the year there were more than 1300.

Investigation showed that those infected were users of the water supplied by the water company, and that practically no cases occurred among those who drank well-water from Fall Creek. Although the University was supplied by the latter, a large proportion of the student body lived in boarding-houses supplied by the company, and among these the epidemic found many victims. Accounts as to the number of students seized are very variable, for a large proportion left town during the height of the outbreak and were sick elsewhere; but they agree that several hundred were seized and more than 40 died. According to Coville[1], about 200 students had typical typhoid after leaving town.

Although it was evident that the cause of the disease was the water of Six-mile Creek and perhaps that of Buttermilk Creek, it was impossible to trace the original infection; but the head-waters of the former drain a district within which considerable typhoid fever had been known to exist within previous years, and, as has been stated, there was abundant opportunity for any infective material to have

[1] American Medicine, January 19, 1904.

reached the water directly. Furthermore, the rate of flow is so great and the total volume of water so small that infective matter discharged into the head-waters could have reached the pumping-station within four hours; and, there being no storage, it could have been delivered in a fresh condition to the consumers.

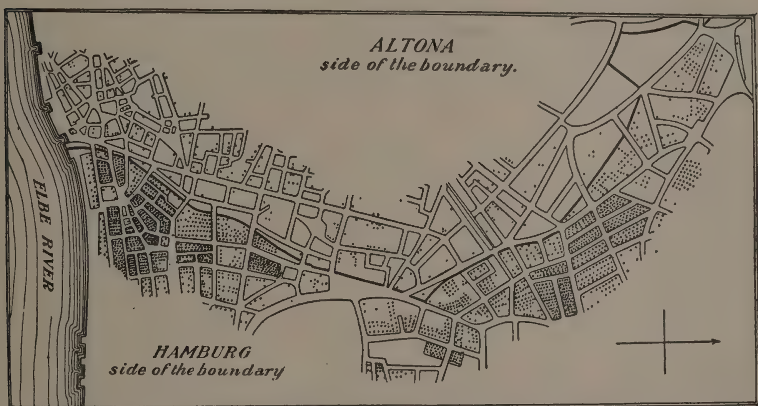
Asiatic Cholera.—This disease, which is endemic in India, whence it makes periodical excursions to other parts of the world, sometimes most widespread and with the most disastrous results, is, perhaps, more exclusively than typhoid fever, a water-borne disease. Since the discovery by Koch of the exciting cause, and the detection of the same in drinking-water during epidemics of the disease, the older theories of its method of spread have been abandoned save by the few remaining adherents of the "localist" theory, whom not even the facts revealed during and after the great epidemic of 1892 can move from their dogged attachment to the creed of their revered teacher.

During the course of the widespread devastating epidemic of 1892, which in its journey from the valley of the Ganges through Persia claimed 20,000 victims in Teheran alone, and in its course through Russia destroyed 215,157 more, and which extended through Germany, Austria, France, Belgium, Holland, and even to the harbors of the Western Hemisphere, no more instructive example of the connection between the disease and polluted water and of the immunity conferred by the use of a pure supply could have been yielded or desired than the experience of Hamburg, Altona, and Wandsbeck. These cities adjoin one another so closely that there is no visible line of demarkation, and in a geographical sense they may be regarded as one place. In one important respect, however, the three places differ very materially; namely, their public water supplies. Wandsbeck was supplied with filtered water from a lake but little subject to pollution; Altona drew upon the Elbe at a point below the entrance of the sewage of Hamburg, but filtered the water through sand; Hamburg used unfiltered water from the Elbe above the city. During the summer of 1892, or between August 17th and October 23d, Hamburg, with a population of 640,000, had nearly 17,000 cases of cholera, of which slightly more than half terminated fatally; Altona, with a population about a quarter as large, had but 500 cases, or only one-thirty-fourth as many (400 of these are supposed to have come from Hamburg), and Wandsbeck had practically none. Very noticeable was the fact that where Hamburg and Altona come together, the Hamburg side was plentifully sprinkled with cases, while the other was comparatively free (see Fig. 36), and this was still more particularly remarked along a certain street that for a distance formed the boundary line, in which the houses on the Hamburg side had plenty of cases and those opposite had none. Almost as though intended for the purpose of marking yet more sharply the distribution of the two kinds of water, it happened that a group of tenement houses on the Hamburg side of the boundary was supplied with water from the Altona mains, and in these houses, densely peopled by

the laboring class, not a single case occurred, while in neighboring houses the disease was raging.

Thus we have a most eloquent instance of the value of sand filtration, and of the danger of using polluted supplies. Hamburg's unfiltered water came from above the city, while Altona had to depend upon water which, before being filtered, had received the entire sewage of more than three-quarters of a million people. The initial specific pollution of the river-water was traced back to Russian emigrants, herded in barracks on one of the wharves pending their embarkation for the United States. At the time of the outbreak, there were, on an average, about a thousand of these people on hand all the time. Many of them came from districts in Russia which had been and were then suffering severely from cholera, and all were well supplied with dirty clothing and blankets, some of which they washed while they were being detained. It is believed that among the thousands that had

Fig. 36.



Portion of the boundary line between Hamburg and Altona. The dots indicate cases of cholera.

arrived, there must have been some mild cases of the disease, or at least some convalescents with cholera germs still in their evacuations two or three weeks after recovery. All of the sewage matters of every description from these people were discharged directly into the river at the wharf.

With the exception of a few straggling cases, there was no cholera in either of the two cities from October 23d to December 6th, when a small outbreak occurred in Hamburg. This reached its culminating point, 5 cases in one day, on the 26th, and then the disease began to reappear in Altona, but under very different conditions from those which characterized the epidemic in August. Of the 500 cases which then occurred, about 400 were connected in one way or another with Hamburg, but in the later outbreak, most of the patients were of the well-to-do class of workmen whose occupation did not call them to Hamburg—women, young children, inmates of hospitals, and others

having no reason to go there. Consultation of the records of bacteriological examination of the Altona filtered water showed an increase in the first week of December, and again in the last days of that month, and at intervals in January, which indicated that some disturbance must have occurred in the working of the filters. Investigation showed where the fault lay, and also its nature: the surface of the sand had been frozen under the mud layer, and had thawed over only a part of its area, so that the whole work of the filter was thrown upon a part. The imperfect working in early December was not followed by cholera, for at that time the river was practically free from the germs. Then came the few new cases in Hamburg, 27 in number, and reinfection of the Elbe, followed by faulty working of the Altona filters, and consequent distribution of a small amount of infective material through the water mains. The organisms were found in the water just below the mouth of the main sewer of Hamburg, and also in one of the settling basins of the filter plant, where the water stood prior to delivery to the beds.

The Propagation of Cholera in India.—As has been stated, the home of cholera is India, and so long as the natives are faithful to their religion and to the observance of old-established customs, just so long will that country supply the rest of the world with occasional infection. Considering the extreme conservatism of all classes of East Indians and the national reverence of the Hindoos for holy places, it may be safe to predict that before any marked change for the better is accomplished, the rest of the civilized world will have advanced so far in sanitary affairs that cholera will be feared no more than varicella. As illustrative of what sanitary reform in India would have to encounter, the following extracts from the report of Dr. Simmons, quoted by Professor Mason, will be found of interest. It may be stated by way of explanation that Orissa, below mentioned, is a province covering more than 24,000 square miles, every part of which is holy ground. Every town contains consecrated land and is filled with temples, and every little hamlet has its shrine.

"The drinking-water supply is derived from wells, so-called 'tanks' or artificial ponds, and the water-courses of the country. The wells generally resemble those in other parts of Asia. The tanks are excavations made for the purpose of collecting the surface-water during the rainy season and storing it up for the dry. Necessarily they are mere stagnant pools. The water is used not only to quench thirst, but is said to be drunk as a sacred duty. At the same time, the reservoir serves as a large washing-tub for clothes, no matter how dirty or in what soiled condition, and for personal bathing. Many of the water-courses are sacred; notably the Ganges, a river 1,600 miles long, in whose waters it is the religious duty for millions, not only of those living near its banks, but of pilgrims, to bathe and to cast their dead.

"The Hindoo cannot be made to use a latrine. In the cities he digs a hole in his habitation; in the country he seeks the fields, the hillsides, the banks of streams and rivers, when obliged to obey the calls

of nature. Hence it is that the vicinity of towns and the banks of the tanks and water-courses are reeking with filth of the worst description, which is of necessity washed into the public water supply with every rainfall. Add to this the misery of pilgrims, their poverty and disease, and their terrible crowding into the numerous towns which contain some temple or shrine, the object of their devotion, and we can see how India has become and remains the hot-bed of the cholera epidemic.

"In the United States official report, the horrors incident upon the pilgrimages are detailed with appalling minuteness. W. W. Hunter, in his Orissa, states that 24 high festivals take place annually at Juggernaut. At one of them, about Easter, 40,000 persons indulge in hemp and hasheesh to a shocking degree. For weeks before the car festival in June and July, pilgrims come trooping in by thousands every day. They are fed by the temple cooks to the number of 90,000. Over 100,000 men and women, many of them unaccustomed to work or exposure, tug and strain at the car until they drop exhausted and block the road with their bodies. During every month of the year a stream of devotees flows along the great Orissa road from Calcutta, and every village for three hundred miles has its pilgrim encampments.

"The people travel in small bands, which at the time of the great feasts actually touch each other. Five-sixths of the whole are females, and 95 per cent. travel on foot, many of them marching hundreds and even thousands of miles, a contingent having been drummed up from every town or village in India by one or other of the three thousand emissaries of the temple, who scour the country in all directions in search of dupes. When those pilgrims who have not died on the road arrive at their journey's end, emaciated, with feet bound up in rags and plastered with mud and dirt, they rush into the sacred tanks or the sea, and emerge to dress in clean garments. Disease and death make havoc with them during their stay; corpses are buried in holes scooped in the sand, and the hillocks are covered with bones and skulls washed from their shallow graves by the tropical rains.

"The temple kitchen has the monopoly of cooking for the multitude, and provides food which, if fresh, is not unwholesome. Unhappily, it is presented before Juggernaut, so becoming too sacred for the minutest portion to be thrown away. Under the influence of the heat it soon undergoes putrefactive fermentation, and in forty-eight hours much of it is a loathsome mass unfit for human food. Yet it forms the chief sustenance of the pilgrims, and is the sole nourishment of thousands of beggars. Some one eats it to the very last grain. Injurious to the robust, it is deadly to the weak and wayworn, at least half of whom reach the place suffering under some form of bowel complaint. Badly as they are fed, the poor wretches are worse lodged.

"Those who have the temporary shelter of four walls are housed in hovels built upon mud platforms about four feet high, in the center of each of which is the hole which receives the ordure of the household,

and around which the inmates eat and sleep. The platforms are covered with small cells without any windows or other apertures for ventilation, and in these caves the pilgrims are packed, in a country where, during seven months out of twelve, the thermometer marks from 85° to 100° F. Hunter says that the scenes of agony and suffocation enacted in these hideous dens baffle description. In some of the best of them, thirteen feet long by ten feet broad and six and one-half high, as many as eighty persons pass the night. It is not, then, surprising to learn that the stench is overpowering and the heat like that of an oven. Of 300,000 who visit Juggernaut in one season, 90,000 are often packed together for a week in 5,000 of these lodgings. In certain seasons, however, the devotees can and do sleep in the open air, camping out in regiments and battalions, covered only by the same meagre cotton garments that clothe them by day.

"The heavy dews are unhealthy enough; but the great festival falls at the beginning of the rains, when the water tumbles in solid sheets. Then lanes and alleys are converted into torrents or stinking canals, and the pilgrims are driven into the vile tenements. Cholera invariably breaks out. Living and dead are huddled together. In the numerous so-called corpse-fields around the town as many as forty or fifty bodies are seen at a time, and vultures sit and dogs lounge lazily about gorged with human flesh. In fact, there is no end to the recurrence of incidents of misery and humiliation, the horrors of which, says the Bishop of Calcutta, are unutterable, but which are eclipsed by those of the return journey. Plundered by priests, fleeced by landlords, the surviving victims reel homeward, staggering under their burdens of putrid food wrapped up in dirty clothes, or packed in heavy baskets or earthenware jars. Every stream is flooded, and the travellers have often to sit for days in the rain on the bank of a river before a boat will venture to cross.

"At all these points the corpses lie thickly strewn around (an English traveller counted forty close to one ferry), which accounts for the prevalence of cholera on the banks of brooks, streams, and rivers. Some poor creatures drop and die by the way; others crowd into the villages and halting-places on the road, where those who gain admittance cram the lodging-places to over-flowing, and thousands pass the night in the streets, and find no cover from the drenching storms. Groups are huddled under the trees; long lines are stretched among the carts and bullocks on the roadside, their hair saturated with the mud on which they lie; hundreds sit on the wet grass, not daring to lie down, and rocking themselves to a monotonous chant through the long hours of the dreary night.

"It is impossible to compute the slaughter of this one pilgrimage. Bishop Wilson estimates it at not less than 50,000. And this description might be used for all the great Indian pilgrimages, of which there are probably a dozen annually, to say nothing of the hundreds of smaller shrines scattered through the peninsula, each of which attracts its minor hordes of credulous votaries. So that cholera has

abundant opportunities for spreading over the whole of Hindostan every year by many huge armies of filthy pilgrims; and the country itself well deserves the reputation it universally possesses of being the birthplace and settled home of the malady."

Parasites and Drinking-water.

There is abundant evidence of the agency of drinking-water in the spread of certain of the animal parasites, but with respect to certain others the danger is much over-rated (tape-worms), or, indeed, imaginary (trichinæ).

Round worms, **Ascaris lumbricoides**, undoubtedly are spread in part by water. The female deposits enormous numbers of eggs in the small intestine, and these are expelled in the fæces. Whether the freshly discharged eggs are capable of reproducing the worm, is a matter of doubt; but it seems probable that the intervention of another host is necessary. Wherever this parasite is known to prevail extensively, the people use polluted water for drinking.

Pin worms, or seat worms, **Oxyuris vermicularis**, are spread probably by water. They locate in the cæcum and upper colon, where the female deposits eggs in large numbers, which, reaching a water-supply after being discharged through the bowel, may be taken into the stomach, where the envelope of the embryo is disintegrated by the gastric juice. The larvæ develop in the small intestine and come to maturity in about four weeks.

Guinea worms, **Dracunculus medinensis**, are said to invade the body through the skin during bathing or through the stomach in drinking-water; the evidence of the latter method is definite. In the stomach, the embryos are developed rapidly, and soon the impregnated female proceeds from the alimentary canal to the subcutaneous tissues in various parts of the body, where she finally breaks through the skin and escapes. The living embryos which are then liberated, finding their way into fresh water, enter the bodies of the common fresh-water flea, *Cyclops quadricornis*, which acts as the intermediate host and conveys the organism to the human stomach. In a case reported by Dr. John Patterson,[1] the patient had an abscess on the upper part of the left tibia, from which, when it was excised, a portion (4 inches) of a worm was removed. Later, he had an abscess and sinus of the left calf, followed by a swelling back of the inner malleolus, and in this a portion of a worm, 25 inches in length and devoid of a head, was found. Dr. Edward Francis[2] had under observation for six weeks at the U. S. Immigrant Hospital (N. Y.), a native of the Gold Coast, who arrived in June, 1901, with a history of having been troubled with these parasites during the preceding three months. During his stay at the hospital five worms appeared: one on the front of the right ankle, one on the dorsum of the right foot, one on the front of the left ankle, one

[1] Medical Record, October 7, 1899.
[2] American Medicine, October 26, 1901.

below the left external malleolus, and one on the dorsum of the left foot, near the toes. One worm presented 26 inches in one piece; the others measured 10 to 18 inches, but were removed in pieces.

Whip worms, **Trichocephalus dispar**, which are said to be extremely common in Paris and some other places outside the tropics, are spread wholly by water, without which the embryo cannot develop within the egg. Taken into the stomach, the envelope is dissolved and the liberated larva attaches itself to the wall of the intestine, where it proceeds very slowly to develop. It does not reach full maturity until about a year has elapsed.

Filaria sanguinis hominis, the parasite which produces chyluria, hæmatochyluria, and elephantiasis, is believed to find its way into the system through water contaminated by mosquitoes which have sucked the blood of persons suffering from the parasite. The adult female produces an enormous number of minute embryos, which pass into the blood; and when these are taken into the stomach of the mosquito, they wander to other parts of the insect, where they become farther developed, and later may be transferred to water, through which they are believed to pass into the human stomach, where the cycle is completed. This parasite is not confined wholly to the tropics, and occasionally is seen in our Southern States. (See Chapter XII.)

Bilharzia hæmatobia, the cause of a peculiar hæmaturia common in parts of Africa, is believed by many to be transmitted by drinking-water contaminated by the urine of persons suffering with the disease. The embryos probably enter the system of some other organisms, which play the part of intermediate hosts and advance their development one stage.

Ankylostomum duodenale (Uncinaria duodenalis), the cause of the anæmia formerly supposed to be peculiar to miners and others engaged in underground operations, was until recently believed to be disseminated chiefly by polluted water; but, as has been said in the consideration of the relation of soil to disease, this idea is no longer tenable, the chief, if not the only, source of infection being soil polluted by the intestinal discharges of those already infected with the parasite.

Strongyloides intestinalis, the parasite of an endemic diarrhœa of Cochin China, first described by French investigators who discovered its rhabditiform embryos in the stools of soldiers returning from China in 1876, was found by Perroncito to occur in association with *Ankylostomum duodenale* in the discharges of laborers afflicted with "St. Gothard tunnel anæmia", has been reported in various countries of Europe, in Egypt, Brazil, the Indies, and Philippine Islands, and within recent years in various parts of the United States. According to Dr. M. L. Price[1], the occurrence of eggs in the stools is very rarely observed, unless there coexists an uncinarial infection, and the parasite is probably introduced by way of the mouth as the filariform embryo, though infection of animals has been produced by means of the eggs. He believes that the vehicle by which the parasite gains access to the

[1] Journal of the American Medical Association, September 12 and 19, 1903.

system is frequently the drinking water, but that fresh vegetables from land manured with human excreta play a part. It is the belief of Stiles that the geographical distribution of the parasite in this country will be found to correspond to that of uncinaria.

ICE.

It is a common idea that ice is necessarily pure, because, in freezing, "water purifies itself." Ice may, however, be quite as impure as the original water or very pure, according to circumstances. The first formation is quite likely to contain impurities, such as the dust and other matters floating on the surface. Under ordinary conditions, the impurities will be limited to this layer, for, in the growth of the ice from above downward, all but traces of dissolved substances and practically all of the suspended matters are excluded.

Ice may become impure in several ways. If snow falls upon it and becomes wet either by rain or by water from below, and then freezes and becomes part of the ice, it will contain all the impurities which have been washed out of the air. If, while the ice is thin, holes are cut so as to permit flooding from below, it will contain all the impurities of the water. Cut from shallow ponds, it will be pure or impure according to the quality of the water and the depth to which it freezes. Water from such ponds, if polluted by surface washings or sewage matters, is likely to yield ice which, when melted, will give off offensive odors.

It is a common belief that bacteria are killed in ice, but many varieties will retain their vitality in it for a very long time. As early as 1871, Burdon Sanderson showed that even the purest ice is likely to contain them in some degree. Chantemesse and Widal proved in 1882, Prudden in 1887, and Riche, Fränkel, and others at different times, that pathogenic bacteria may maintain their vitality to a surprising degree in ice, and that the bacillus of typhoid fever is particularly resistant. Prudden[1] showed that ice, made from water which contained them to an innumerable extent, yielded at the expiration of 103 days no less than 7,348 per cc.

Bacteria are resistant not only to the ordinary low temperature of ice, for Pictet and others have proved that even the extraordinary cold of liquefied air, —315° F., is not sufficient to destroy them. On the other hand, Sedgwick and Winslow,[2] W. H. Park,[3] and H. W. Hill,[4] who have made independent investigations of the possible danger of ice as a cause of outbreaks of typhoid fever, agree that it is but slight. Sedgwick and Winslow found that the bacilli perish rapidly; 50 per cent. at the end of the first week, 90 per cent. in two weeks, and practically all (2 or 3 in 1000 remained) after twelve weeks. It is pointed out by the several observers named that the majority of bacteria in water are eliminated in the process of freezing; that the majority of those included die within a few weeks; that the bacteria

[1] Medical Record, March 26, 1887.
[2] Abstract in Revue Scientifique, April 28, 1900.
[3] Journal of the Boston Society of Medical Sciences, IV., p. 213.
[4] Boston Medical and Surgical Journal, November 21, 1901.

in ice are commonly harmless in character; and that cities which use ice from polluted streams (*e. g.*, New York, Lowell, Lawrence) suffer apparently none at all therefrom. The State Board of Health of Massachusetts says (Annual Report for 1900), concerning the bacterial content of the domestic supply, "In not one instance of the still freezing of ordinarily polluted water . . . . have we been able to find *B. coli* in the ice formed."

Recent experience at Ogdensburg, N. Y., seems to indicate that ice taken from a polluted river having a fairly rapid flow may, however, be a source of danger. In October, 1902, after almost total freedom from typhoid fever for nearly two years, an outbreak occurred among the inmates of the St. Lawrence State Hospital, the water-supply of which was beyond reproach. The attack was purely local, other users of the water not being affected. The possibility of infection from other sources having been eliminated, attention was directed to the ice, and it appeared that, about six days before the development of the first cases, a new supply taken from the St. Lawrence River and stored for more than seven months had been brought into use. Specimens of the ice yield a black sediment, which, on examination by Hutchings and Wheeler,[1] was found to contain bacilli, cultures of which responded to the tests for *B. typhosus*, including clumping when treated with serum from a typhoid patient.

Artificial ice is frozen in blocks of the size and shape of the tanks in which the water is held. As the entire mass of water in each tank is frozen, it naturally must contain in its inner portion, which is the last to freeze, all of the matters originally contained. Unless the water used is pure and colorless, the ice will not be of good quality, and, particularly in the center, will not be of good appearance. When colored or impure water is used, it is a common practice to remove the impurities and coloring matters by tapping the center before the freezing process is completed, and drawing off the liquid in which they have become concentrated. On account of the possible retention of part or all of the contained impurities and bacteria of the water from which it is made, artificial ice should be manufactured only from distilled water or from natural water of the highest degree of purity.

CHEMICAL EXAMINATION OF WATER.

Collection of Samples.—In taking samples of water for chemical analysis, great care is necessary in order to secure specimens which shall be fairly representative of the supply under investigation. They should be taken only in clean glass bottles or demijohns of from half a gallon to a gallon capacity, and never in stone jugs, tin cans, or wooden kegs. The best form of bottle has a glass stopper, but a perfectly clean cork is unobjectionable. In spite of directions most carefully given, one often sees specimens sent in stone jugs stopped with wooden plugs wrapped with old cotton rags or pieces of news-

[1] American Journal of the Medical Sciences, October, 1903, p. 680.

paper to secure a tighter fit, and sometimes smeared with shoemakers' wax, pitch, or even tallow. Analysis of such specimens is likely to give results of no value whatever, for it should be remembered that we are dealing with exceedingly small amounts of ammonia and other products, and that anything short of absolute cleanliness of receptacles introduces error.

The bottle, supposedly clean at the start, should be rinsed thoroughly with the water to be sampled, then filled to the neck, and securely stoppered. If the sample comes from a pump, the barrel of the latter should be emptied completely of the water which has been standing in it for any length of time; if from a pipe, the water should be allowed to run to waste, until the whole of the original contents has escaped; if from a pond or other body of water, the bottle should be plunged sufficiently far beneath the surface to avoid the entrance of floating matters, and at a sufficient distance from the banks to avoid matters that hug the shore.

After the sample is secured, as little time as possible should elapse before beginning the analysis, because of the rapidity with which changes occur in the organic matters, ammonia, nitrites, and nitrates.

Determination of Free Ammonia and Albuminoid Ammonia.

Solutions Required: 1. STANDARD SOLUTION OF AMMONIUM CHLORIDE.—Dissolve 3.138 grams of pure dry ammonium chloride in 1 liter of distilled water free from ammonia. One cc. of this solution represents 1 mgr. of ammonia.

2. STANDARD DILUTE SOLUTION OF AMMONIUM CHLORIDE.—Dilute 10 cc. of the strong solution up to 1 liter with water free from ammonia. One cc. of this solution represents 0.01 mgr. of ammonia.

3. SOLUTION OF SODIUM CARBONATE.—Dissolve 200 grams of pure sodium carbonate in 1 liter of water free from ammonia.

4. ALKALINE POTASSIUM PERMANGANATE.—Dissolve 8 grams of potassium permanganate and 200 grams of caustic potash in 2 liters of distilled water, and boil down to 1 liter, to get rid of any free ammonia present. Fifty cc. of this solution are required for each analysis. The author finds it convenient to omit the boiling-down process when the solution is prepared, and to take 100 cc. and boil down to 50 at the time of analysis. This insures freedom from ammonia when used, and avoids the bumping which is so likely to occur when the cold solution is added during the process of distillation.

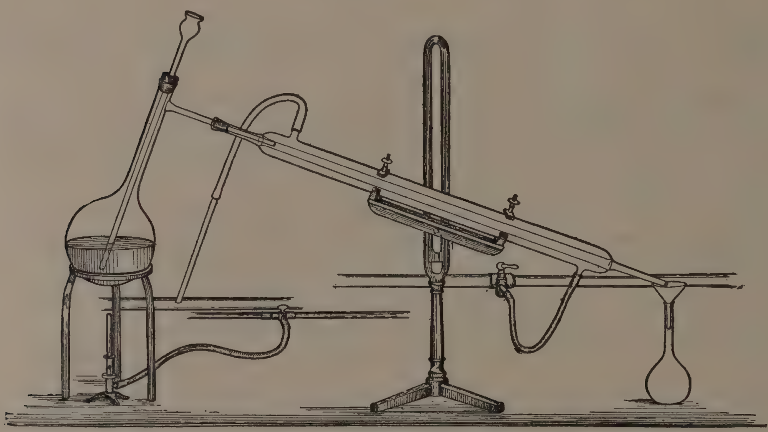
5. NESSLER'S REAGENT.—Dissolve 35 grams of potassium iodide in 150 cc. of distilled water. Dissolve about 16 grams of corrosive sublimate in 300 cc. of distilled water. Add the latter to the former, both solutions being cold. Then add 200 grams of caustic soda, dissolved in 0.5 liter of distilled water, and mix thoroughly. Next add, with constant stirring, a saturated solution of corrosive sublimate until the precipitate which forms is permanent; then dilute the whole to 1

liter. Let stand until clear, when the supernatant liquid should have a pale-straw color.

6. AMMONIA-FREE WATER.—This may be obtained by distilling water made slightly acid with sulphuric acid. The first 25–50 cc. of distillate should be rejected, and the next 50 cc. should be tested with Nessler's reagent. If no color appears, the distillate is ammonia-free, and the operation may then be continued until the contents of the retort are reduced to very small volume. If the test shows traces of ammonia, successive portions should be tested until a negative result is secured. It is well to prepare a goodly supply, and to keep it on hand in glass-stoppered bottles.

Apparatus Required.—Distilling Apparatus.—Some analysts prefer glass retorts; others, distilling flasks with side tubes. Whichever is used, the connection with the Liebig condenser should be tight. The author prefers a distilling flask, with a side tube of such a size that it enters the condenser tube easily, but without making a loose joint. A bit of clean rubber tubing on the side tube may serve to make the joint more perfect at the point of entrance. The mouth

FIG. 37.



Distilling apparatus used in determining the ammonias in water.

of the flask should be closed with a rubber stopper with a single perforation, carrying a funnel tube which reaches to the bottom of the flask.

The flask or retort may be heated either by a rose burner or by the free flame of a Bunsen lamp. In laboratories where water analysis is conducted on a large scale, it is found convenient to have the distilling flasks, arranged in the form of batteries, connected with block tin condensing tubes which pass through a common cooling-tank fed by a single tap.

In Fig. 37 is shown the form of apparatus which the author finds convenient for ordinary work.

Nesslerizing Tubes.—For making the determination of ammonia by the colorimetric method, tubes of colorless glass, about $12\frac{1}{2}$ x $\frac{5}{8}$ inches, with a mark at the 50 cc. point, are required.

Determination.—The flask and condenser are rinsed with ammonia-free water, 0.5 liter of the water and 5 cc. of sodium carbonate solution are introduced into the flask, and heat is applied. The distillate is collected either in the Nessler tubes or in 50 cc. flasks, from which it is transferred to the tubes; and when three portions of 50 cc. each have been collected, all of the free ammonia in the sample will have passed over.

On beginning the distillation, 100 cc. of the unconcentrated alkaline permanganate solution are heated in a small flask and boiled down to 50 cc., and on the completion of the distillation for free ammonia, the hot reagent is added through the funnel tube, and boiling is continued. If the reagent has been concentrated in advance, 50 cc. are added. The nitrogenous organic matter is now attacked by the permanganate solution and more ammonia is evolved. While this in no way differs from the free ammonia, it is given the distinguishing name "albuminoid ammonia," to indicate its origin. The process is now continued as long as ammonia passes over, but usually no reaction is observed after four portions of 50 cc. have been collected. In the laboratory of the State Board of Health of Massachusetts, it is the custom to fill five tubes, and then to cease distilling. To each of the tubes containing the ammonias, 2 cc. of Nessler's reagent are added. In the presence of ammonia, a yellowish-brown color is produced, the depth of which depends upon the amount of ammonia present. Some exceptionally rich waters yield such an amount of ammonia that a precipitate is formed on addition of the reagent. Then it is necessary to repeat the process, and to take an aliquot part of the distillate and dilute it with ammonia-free water to 50 cc. before nesslerizing. Should a precipitate again occur, a smaller part should be taken, and so on until the proper reaction is obtained. The amount in the whole distillate may then be determined mathematically. Having nesslerized the several tubes, the next step is to determine the amounts present by comparison of colors with a scale made as follows: Into a series of tubes, held in a rack, different amounts of the weaker solution of ammonium chloride are introduced, then ammonia-free water is added to each up to the 50 cc. mark, each tube inverted to insure thorough mixing, and, finally, 2 cc. of Nessler's reagent added to each. A convenient scale is secured by using 0.25, 0.50, 0.75, 1.00, 1.50, 2.00, 2.50, 3.00, 3.50, 4.00, and 5.00 cc., representing 0.0025, 0.0050, 0.0075, 0.010, 0.015, 0.020, 0.025, 0.030, 0.035, 0.040, and 0.050 mgr. of ammonia. The first of these will have a very faint yellowish-brown tint, and the last a very decided reddish-brown color, while the intervening tubes show a progressive deepening. With these tubes, the distillates are compared, and the matching of colors gives the desired results. If a given tube falls between any two of the scale, a new comparison

tube may be prepared; but the practised eye can determine very accurately without this extra aid. Having read the color of each tube, the amounts of those representing the free ammonia are added together, and the total multiplied by 2, to get the amount per liter of water; the same process is carried out for the determination of the albuminoid ammonia. The results represent parts per million, since 1 liter equals 1,000,000 milligrams.

EXAMPLE.—The three free-ammonia tubes show 0.023, 0.006, 0.000: total 0.029 mgr.; multiplied by $2 = 0.058$ per liter. By moving the decimal point one place to the left, we have 0.0058 part per 100,000, in which terms the results ordinarily are expressed.

Precautions.—Since the depth of color caused by Nessler's reagent is affected more or less by temperature, and since in all processes of comparison the conditions must be the same so far as is possible, the reagent should not be added until the distillates and the contents of the comparison tubes have the same temperature. Equality in this respect is secured without any manipulation or trouble by leaving the tubes over night, so that all will acquire the temperature of the room. It is hardly necessary to point out that the air of the room in which the distillation is conducted should be quite free from laboratory fumes, such as ammonia and sulphuretted hydrogen, which, being absorbed by the distillate, would, in the one case, give erroneous results, and, in the other, react upon the mercury salt in the Nessler's reagent.

The heat applied to the distilling flask should be so regulated that the time required for each portion of 50 cc. will be about fifteen minutes, since with more rapid distillation there is likely to be some loss of ammonia by imperfect condensation.

The reading of the tubes should not be undertaken until at least five minutes have elapsed after the addition of the reagent. The extreme depth of color obtainable is reached somewhat within that time.

The practice of some analysts of distilling the free ammonia out in one lot of 150 or 200 cc., collecting the albuminoid ammonia in another single portion of 200 or 250 cc., nesslerizing a portion of each, and calculating the total amount of each by multiplication by the proper factor, gives correct results; but it has been shown that by proceeding in this way, one may lose useful information obtainable from a knowledge of the rate at which the ammonia is evolved, since organic matter, well advanced in decomposition, yields it more copiously in the first distillate, whereas fresh material yields it more slowly and uniformly.

Some analysts make duplicate distillations of one water at the same time, determining the free ammonia in one specimen, and, by adding the permanganate at the start in the other, determining the total free and albuminoid ammonia together. By subtracting the lesser from the greater, the amount of albuminoid ammonia is obtained.

Permanent Ammonia Standards.—In order to avoid the necessity of preparing standards each time they are required, for those made as above soon undergo change, Mr. D. D. Jackson[1] has proposed making a permanent set with potassium platinic chloride and cobaltous chloride, with which, with a little practice, the Nessler solution may be prepared to fit exactly. Since his method of preparing the latter differs materially from that above described, it is reproduced here: "Dissolve 61.75 grams of potassium iodide in 250 cc. of redistilled water, and add a cold solution of mercuric chloride which has been saturated by boiling with excess of the salt. Pour in the mercury solution cautiously, and add an amount just sufficient to make the color a permanent bright red. With a little practice, the exact depth of color can be easily duplicated. It will take a little over 400 cc. of the mercuric chloride solution to reach this end point. Dissolve the red precipitate by adding exactly 0.75 gram of powdered potassium iodide. Then add 150 grams of potassium hydrate dissolved in 250 cc. of water. Make up to 1 liter. Mix thoroughly and allow the precipitate formed to settle. It is best to make up a large amount of Nessler solution, and if by its use the ammonia standards do not fit the artificial ones prepared from the platinum and cobalt solutions, a little more mercuric chloride to increase sensitiveness, or potassium iodide to decrease it, will bring the Nessler solution to the point where, if just 2 cc. are used, the regular ammonia standards will exactly fit the artificial ones. . . . Of course, each new lot of Nessler solution should be compared, to see that it has the proper degree of sensitiveness to fit the standards."

To prepare the permanent standards, two separate solutions, one of potassium platinic chloride and one of cobaltous chloride, are necessary. The first is made by dissolving 2 grams of the salt in a small amount of water, adding 100 cc. of strong hydrochloric acid, and diluting to 1 liter. The second, by dissolving 12 grams of the salt in water, adding 100 cc. of strong hydrochloric acid, and diluting to 1 liter.

"Varying amounts of these two solutions are required, because the color of the Nessler standards becomes more and more reddish as the amount of ammonia increases. The standards are made up in 50 cc. Nessler tubes 1.7 cm. ($\frac{11}{16}''$) in diameter and 21 cm. ($8\frac{1}{4}''$) from the bottom to the 50 cc. mark." Sixteen standards are prepared with distilled water up to the 50 cc. mark, as follows:

Pt. solution. cc.		Co. solution. cc.		Ammonia. mgr.	Pt. solution. cc.		Co. solution. cc.		Ammonia. mgr.
1.0	+	0.0	=	0.000	12.7	+	2.2	=	0.020
1.8	+	0.0	=	0.001	15.0	+	3.3	=	0.025
3.2	+	0.0	=	0.003	17.3	+	4.5	=	0.030
4.5	+	0.1	=	0.005	19.0	+	5.7	=	0.035
5.9	+	0.2	=	0.007	19.7	+	7.1	=	0.040
7.7	+	0.5	=	0.010	19.9	+	8.7	=	0.045
9.4	+	0.9	=	0.013	20.0	+	10.4	=	0.050
10.4	+	1.3	=	0.015	20.0	+	15.0	=	0.060

[1] Technology Quarterly, XIII., No. 4, December, 1900.

While these agree perfectly with the regular Nessler ammonia standards on lengthwise examination, they do not at all agree on side view, the artificial standards appearing decidedly pink, instead of brownish yellow.

Determination of Other Nitrogen Compounds.—Preliminary Treatment.—Should the specimen of water have an appreciable color, due to dissolved vegetable matters, it is necessary, before attempting the determination of the above-mentioned substances or of the chlorides, to decolorize a sufficient volume by means of milk of alumina. This is prepared by mixing gradually very dilute solutions of sodium hydrate or ammonia and alum or aluminum sulphate; the resulting precipitate is allowed to settle, and is then washed several times by decantation. The water used in washing should be free from chlorides, nitrates, and nitrites. If strong solutions are used, the gelatinous precipitate soon undergoes change both in appearance and character. It becomes chalky and loses its property of removing color. In order to remove all coloring matter, 0.5 liter of the water may be shaken in a flask with a few cc. of the thick "milk," and then filtered through paper. By this means, the most highly colored swamp waters are made colorless in a very few minutes.

Determination of Nitrogen as Nitrites.—Solutions Required.—1. Sulphanilic Acid Solution (paramidobenzene-sulphonic acid).—Dissolve 0.50 gram in 150 cc. of acetic acid (sp. gr. 1.040).

2. Naphthylamine Solution (*a*-amidonaphthalene).—Dissolve 0.10 gram. in 20 cc. of boiling water, filter, and add 180 cc. of acetic acid (sp. gr. 1.040).

3. Standard Sodium Nitrite Solution.—Dissolve 0.275 gram of pure nitrite of silver in pure distilled water and add a dilute solution of pure sodium chloride until precipitation ceases. Dilute to 250 cc. and preserve in the dark in an amber bottle.

4. Standard Dilute Sodium Nitrite Solution.—Dilute 10 cc. of the preceding to 1 liter with pure distilled water and preserve in the same way. One cc. equals 0.001 mgr. of nitrogen as nitrite.

Process.—To 50 cc. of water in a Nessler tube, or to 100 cc. in a tube of larger diameter, add 2 cc. of each of the two first-mentioned solutions. If nitrites are present, a pink to a garnet color is developed within a half hour, the intensity of color depending upon the amount of nitrite present. If no change is observable at the end of a half hour, nitrites may be recorded as absent; if, on the contrary, a coloration is produced, the test may be repeated, and at the same time one or more comparison cylinders prepared. In similar tubes, dilute to the mark with distilled water free from nitrites 0.25, 0.50, and 1 cc. of the dilute sodium nitrite solution, and add to each the proper amounts of the test-solutions. At the end of half an hour, compare the color acquired by the water sample with the standards, and multiply by the proper factor, to determine the amount per liter.

Since the air of laboratories in which gas is burning is very likely to contain traces of nitrites, which are absorbed readily by water, it is

well to keep the tubes corked or otherwise protected. A tube left open some hours is almost sure to develop more or less color.

The color reaction is due first to the action of the nitrite present on the sulphanilic acid, whereby a new compound (diazobenzene-sulphonic anhydride) is produced, which is then acted upon by the naphthylamine and converted into another (azo-α-amidonaphthalene-parazobenzene-sulphonic acid) which imparts the color.

Permanent Nitrite Standards.—Mr. Jackson has proposed employing permanent standards for the nitrite determination also. They are made from two solutions, one made by dissolving 24 grams of cobaltous chloride in distilled water, adding 100 cc. of strong hydrochloric acid, and diluting to 1 liter; and the other by dissolving 12 grams of dry cupric chloride, adding 100 cc. of strong hydrochloric acid, and diluting likewise to 1 liter. The standards are made up in 100 cc. tubes, 3 cm. ($1\frac{1}{8}''$) in diameter and 13.2 cm. ($5\frac{1}{4}''$) to the 100 cc. mark. The following table gives the proportions of each solution to be made up to the 100 cc. mark:

Co. solution. cc.		Cu. solution. cc.		Parts of N as nitrite per million.
1.1	+	1.1	=	0.001
3.5	+	3.0	=	0.003
6.0	+	5.0	=	0.005
12.5	+	8.0	=	0.010
20.0	+	8.0	=	0.015

The method of determining nitrites, as given by Mr. Jackson, is as follows: Fill a 100 cc. Nessler tube with the water to be tested, add 1 cc. of hydrochloric acid (1 : 4), then 2 cc. of sulphanilic acid (8 grams per liter), and finally 2 cc. of naphthalamine hydrochlorate (8 grams per liter with 10 cc. of strong hydrochloric acid); allow to stand twenty minutes until the full development of the color appears. If 100 cc. of water develop a color corresponding to the second of the above standards, for example, it contains 0.003 part per 1,000,000 of nitrogen as nitrite.

Determination of Nitrogen as Nitrates.—Solutions Required.—1. Phenoldisulphonic Acid.—Heat together for six hours in a water-bath 555 grams of strong sulphuric acid and 45 grams of pure phenol. Should the resulting compound solidify on cooling, it may be liquefied again in the bath and then poured into a number of small bottles provided with ground stoppers. Then, as needed, one of them may be placed in the bath and the contents liquefied.

2. Standard Solution of Potassium Nitrate.—Dissolve 0.722 gram of pure potassium nitrate in 1 liter of pure distilled water. One cc. equals 0.1 mgr. of nitrogen as nitrates.

Process.—Evaporate 10 cc. or more of the water with 1 drop of sodium carbonate solution to dryness in a small porcelain dish. To the residue, add 1 cc. of phenoldisulphonic acid, which should be brought into contact with every particle by means of a glass rod. Dilute with water, make strongly alkaline with ammonia or caustic

potash, and, finally, make up to 50 or 100 cc. with water. Evaporate measured volumes of the standard nitrate solution, treat the residues with a like amount of the reagent, and proceed in the same way to make a comparison scale. The addition of the alkali converts the picric acid, formed by the action of the nitrate on the phenoldisulphonic acid, into the corresponding picrate, which imparts a bright-yellow color, the intensity of which depends upon the amount of nitrate present. The comparison of tints may be made directly in the porcelain dishes or in tubes of the same sort as used in the nitrite determination.

The accuracy of the test is diminished by the presence of chlorides in notable amounts, say more than 2 parts in 100,000, but not by nitrites. On this account, Mason recommends the addition of corresponding amounts of sodium chloride in the preparation of the color scale.

The standards made as above do not change on keeping, and hence may be made up in sets and preserved.

Determination of Chlorine.—Solutions Required.—1. Standard Solution of Silver Nitrate.—Dissolve 4.797 grams of pure silver nitrate in 1 liter of distilled water. One cc. of this solution is the equivalent of 1 mgr. of chlorine.

2. Solution of Potassium Chromate.—Dissolve 5 grams of potassium chromate in 100 cc. of distilled water, add nitrate of silver solution, for the removal of any traces of chlorides present, until a red precipitate of chromate of silver is formed. Let stand, and separate the precipitate by decantation or filtration. This solution is to be used as an indicator.

Process.—Place in each of two beakers of similar size 100 cc. of water and 5–10 drops of the indicator. The beakers standing side by side upon a white surface of porcelain or filter-paper, the silver nitrate solution is added to one of them from a burette little by little until, in spite of stirring with a glass rod, a faint reddish tinge begins to be perceptible. This is seen more easily by comparison with the water in the other beaker. The burette reading is now taken, and then a drop or two more of the reagent will, by intensifying the red color, show that the end point has been reached. The process depends upon the fact that silver has a greater affinity for chlorides than for chromates, and that, so long as any of the former is present, no permanent union will occur with the latter. When, however, all the chlorine has combined with the silver, the red chromate begins to form, and makes its presence known by the change of color. On completion of the process, the amount of the standard reagent used indicates the amount of chlorine present, each cc. used representing 1 milligram.

Inasmuch as a certain amount of the reagent is required to give the beginning tint in 100 cc. of distilled water, a correction should be made before setting down the result. This amount differs somewhat with different observers, since all eyes are not equally quick to discern the appearance of the reddish tint, and hence the best method of fixing

the amount to be subtracted is for each one to determine it himself by experimenting with 100 cc. of distilled water containing the requisite amount of the indicator.

Should the amount of chlorine in a given sample be so small that the end reaction appears on the addition of but a few drops of the silver solution, it is best to concentrate 250 or 500 cc. of the water to 100 cc., and repeat the titration.

Determination of Residue.—Evaporate 100 cc. of water to dryness in a perfectly clean, dry, accurately weighed platinum dish. When completely evaporated, transfer the dish from the water-bath to an air-bath kept at 105° C., and leave it for an hour, at the expiration of which time, place it in a desiccator to cool. Reweigh and note the gain in weight, which represents the amount of total solids in the volume of water taken. The number of milligrams gained represents the number of parts per 100,000. The weighing should be done as quickly as possible, in order to avoid error due to the absorption of atmospheric moisture by hygroscopic matters in the residue.

In order to determine the amount of volatile substances, the dish is next heated to dull redness on a platinum triangle over a Bunsen lamp. The organic matter, in the process of burning off, gives rise to more or less blackening, and may also evolve odors which often convey some idea of its nature. The blackening may disappear quickly or may persist for some time, especially in the case of woody matters, such as are present in brown swamp waters. Animal matters cause an odor like that of burnt horn; vegetable substances, one suggestive of burning peat. The loss in weight represents not only the organic matter, but also the nitrates, nitrites, ammonium salts, combined carbonic acid, and, if the temperature has been raised too far, part of the chlorides. The residue after ignition represents the "fixed solids."

Determination of Hardness.—For the determination of hardness, a number of processes are in use; but for practical utility, that known as the "soap method" is to be preferred.

Solutions Required.—1. STANDARD SOLUTION OF CALCIUM CHLORIDE.—Weigh out 1 gram of pure calcium carbonate, dissolve it in as little as possible dilute hydrochloric acid, and evaporate to dryness. Add to the residue a little distilled water, and again evaporate to dryness. Dissolve in distilled water and make up to 1 liter. One cc. represents 1 milligram of calcium carbonate.

2. STANDARD SOLUTION OF SOAP.—Scrape about 10 grams from an old dry piece of pure Castile soap free from sodium hydrate and carbonate, and dissolve it in 1 liter of diluted alcohol. Let stand over night and filter. This should next be standardized in the following manner: To 100 cc. of distilled water contained in a glass-stoppered bottle of about 250 cc. capacity, run in, from a burette, successive small portions of the soap solution until, on vigorous shaking, a lather is formed which persists at least two minutes, and note the amount used.

Repeat the operation with 99 cc. + 1 cc. of the standard solution of

calcium chloride, and then with 2, 3, 4, 5, 6, 7, 8, 9, and 10 cc. of the same solution made up to 100 cc. with distilled water, and note the amount used in each test. It will not suffice to determine the amount necessary to produce a lather with distilled water and with 10 cc. of the calcium chloride solution, made up to the same volume, and divide the difference by 10, since as we go up in the scale a gradual lessening of the amount of increase for each degree is noted. In this way we obtain a scale of values for the particular lot of soap solution made at one time. It will save some trouble if one makes up a number of liters, but it is necessary to make occasional tests to see that the strength does not deteriorate, or, if it does, to correct the scale.

PROCESS.—To 100 cc. in the bottle above mentioned, add the soap solution in the same manner as employed in making the scale, and, when the end point is reached, note the amount used, and, by reference to the scale, ascertain the number of degrees of hardness. Should the water be harder than 10 degrees, it is best to take a smaller amount and make it up to 100 cc. with distilled water and then proceed anew, remembering at the end to calculate accordingly.

The result obtained expresses the "total hardness." If it be desired to ascertain the temporary, or removable, hardness, 100 cc. of the water may be boiled five minutes and then allowed to cool. The original volume is restored by the addition of the necessary amount of distilled water, and then the operation is repeated. The second result indicates the permanent hardness, and the difference, if any, is the temporary hardness.

Determination of "Oxygen Required."—All organic substances are susceptible of oxidation; but as they are widely variable in character, they require very different amounts of oxidizing agents for the attainment of the same result. The several methods proposed for determining the oxygen-consuming capacity of drinking-waters have, therefore, only a limited value; but, in general, it may be said that a high requirement indicates an amount of organic matter inconsistent with purity when it cannot be accounted for by the presence of ferrous salts. Since the amount of organic matter is indicated pretty fairly by the ammonia and albuminoid-ammonia determinations, the estimation of the "oxygen required" serves only as confirmatory evidence.

Solutions Required.—1. STANDARD SOLUTION OF POTASSIUM PERMANGANATE.—Dissolve 0.395 gram in 1 liter of distilled water. One cc. is equivalent to 0.1 mgr. of available oxygen.

2. STANDARD SOLUTION OF OXALIC ACID.—Dissolve 0.7875 gram in 1 liter of distilled water. One cc. corresponds to an equal measure of the permanganate solution.

3. DILUTE SULPHURIC ACID, 1 : 3.

PROCESS.—The determination is based on the fact that potassium permanganate gives up its oxygen readily to organic matter, especially in the presence of acid and with the application of heat. The reaction is expressed in the following equation:

$$4KMnO_4 + 6H_2SO_4 = 2K_2SO_4 + 4MnSO_4 + 6H_2O + 5O_2.$$

Thus 4 molecules of permanganate will yield 5 of oxygen, or, differently expressed, 632 parts by weight of the one will yield 160 parts by weight of the other; hence, 3,950 of permanganate equals 1,000 of oxygen.

In this operation, cleanliness of vessels is of the greatest importance. A porcelain casserole or evaporating dish of sufficient size is made fit for use by boiling it in distilled water acidulated with sulphuric acid, and adding permanganate solution until no further decoloration is observed.

Place 200 cc. of the sample in the dish, add 10 cc. of the dilute sulphuric acid, and heat to boiling. Add from a burette sufficient of the permanganate solution to cause a very distinct redness, and boil again, adding the permanganate as the color tends to fade, so as to retain as nearly as possible the original color. When farther boiling for five to ten minutes fails to diminish the intensity of the color, oxidation is complete. Add now 10 cc. of the oxalic acid solution, which will discharge the color if the permanganate has not been added too freely. Should the color not be discharged by 10 cc., add 10 more. Having now a colorless solution, add more permanganate until a slight pink color again appears. Note the total amount of permanganate used, subtract from it that used up by the oxalic acid, multiply the number of cc. remaining by 5, in order to arrive at the amount which would be consumed by 1 liter, and divide by 10 to express the result in milligrams of oxygen. Inasmuch as any nitrites present are oxidized to nitrates, a correction should be made for them. This can be done very readily, since 16 parts of oxygen are required for 14 parts of nitrogen as nitrites.

Since the permanganate solution is not wholly stable, it should be titrated against the oxalic acid solution every time it is used. This may be done most conveniently by adding, after the operation is completed and the reading of the burette is noted, 10 cc. more of the oxalic solution and titrating to the same point as before.

The oxalic solution keeps better, if a few cc. of strong sulphuric acid are added when it is being diluted to 1 liter.

Determination of Color.—The color of water may be observed by viewing a sufficient depth of the specimen in a glass cylinder against a white surface. Color may be expressed quantitatively by comparison with the standards for the ammonia determinations.

Determination of Odor.—Place about 200 cc. of water in a 500 cc. beaker, cover with a watch-glass, and heat to about 40° C. Give the beaker a rotary motion, so that the water is set in motion, remove the watch-glass, and with the nose well inside the beaker note the character of the odor. Some analysts prefer to heat the water in a glass-stoppered bottle, the use of which permits a much more thorough agitation of the water before applying the nose. The odor should be designated according to the substance which its presence suggests.

Determination of Reaction.—A most delicate reagent for alkalinity in water is a 1 per cent. solution of toluylene-red. Fifty cc. of water

distinctly alkaline will become intensely yellow on the addition of 2 or 3 drops. A less degree of alkalinity will cause an orange or pale-red color. It is so delicate a test that 1 part of alkaline carbonate in 1,000,000 is revealed by it.

The presence of acids is shown by another sensitive indicator, lacmoid. This is not affected by carbonic acid, nor by ferrous and other metallic salts which are acid to litmus, but is affected by ferric salts. It may be used as a 1 per cent. solution in diluted alcohol. Phenolphthalein solution, 0.5 per cent., is colorless in neutral and acid solutions, and pink in alkaline. It is affected by carbonic acid.

In the determination of reaction, a drop or two of the indicator may be added to a volume of the water in a long glass tube. A very faint change, due to acids or alkalies, is perceptible on looking down through the column against a white background. If the reaction is acid, the sample should be boiled, then cooled, and tested again to ascertain if the acidity is due wholly or in part to carbonic acid. Acidity and alkalinity are determined quantitatively by titration with centinormal solutions of sodium hydrate and hydrochloric acid, using lacmoid or phenolphthalein and methyl-orange as indicators.

Determination of Turbidity.—For the determination of the degree of turbidity, several methods are in use, among which the following may be mentioned: Mason[1] recommends standards made by adding weighed amounts of kaolin to distilled water, each representing parts per 1,000,000 of kaolin. Whipple and Jackson[2] employ finely powdered diatomaceous earth, instead of kaolin, because of the greater uniformity in the size of the particles. Hazen[3] measures it by determining the depth at which a 0.1 mm. platinum wire can no longer be seen.

Detection and Determination of Lead.—Many processes have been proposed for both qualitative and quantitative determination of this most undesirable contamination. The simplest test, but by no means the best, consists in adding a drop or two of ammonium sulphide to a volume of water in a tall glass cylinder, and noting the character of the discoloration produced. If darkening occurs, due to the formation of a metallic sulphide, the addition of dilute hydrochloric acid will distinguish between lead and iron, the sulphide of the latter being soluble. To those who have had practical experience in detecting minute amounts of metals in water, this method is far from satisfactory. More or less color is imparted by the ammonium sulphide, and more or less turbidity is produced commonly on the addition of the acid. Moreover, when unconcentrated water is used for the test, no reaction may occur, although the poisonous metal is present in minute traces.

Another simple test, depending upon the formation of lead chromate, has been offered by S. Harvey,[4] who claims that water containing 0.30

[1] Journal of the American Chemical Society, XXI., p. 516.
[2] Technology Quarterly, XIII., No. 3, September, 1900.
[3] Journal of the Franklin Institute, 1899, p. 177.
[4] The Analyst, April, 1890.

milligram of lead in 1 liter will show a turbidity from chromate when 250 cc. are treated with 0.10 gram of potassium bichromate; and that in twelve hours the precipitate will settle and become still more distinct.

Since small amounts of lead sulphide remain in solution, and can be separated only with great difficulty when the volume of water is large, it is best to concentrate the specimen to a very small bulk before attempting to precipitate the lead. From this point onward the methods employed vary very considerably.

Liebrich [1] precipitates the lead as sulphide in acid solution, converts it to sulphate by treatment with nitric and sulphuric acids, and dissolves this by warming with a few cc. of caustic potash (1 : 10). The solution is filtered and made up to 20 cc., and 2 cc. of ammonium sulphide are added, whereby a brown color is produced, which may be compared with the shades produced by similar treatment of equal volumes of distilled water containing known amounts of a solution of lead sulphate in caustic potash.

Antony and Benelli [2] recommend the addition of mercurous chloride before precipitation as sulphides, believing that thereby no trace of lead can escape complete separation. The combined sulphides are filtered and dried, then heated to such an extent that the mercury salt is driven off, leaving the lead as a residue.

Mr. H. W. Clark,[3] after trying all known methods, finds most satisfaction in the following process devised in his laboratory: 3,500 cc. are evaporated to 25 or 30 cc., 10 or 15 cc. of ammonium chloride solution added to assist separation of the sulphides, and a considerable excess of strong ammonia. Hydrogen sulphide is then added and the dish allowed to stand some hours, after which more ammonia and hydrogen sulphide are added. After boiling to expel the excess of hydrogen sulphide, the precipitate is filtered off. It contains any lead, iron, copper, or zinc as sulphides, and other suspended organic and mineral substances. It is washed once with hot water, and the paper is then boiled in dilute nitric acid (1 : 5). It is then filtered, and washing is continued as long as any acid is removed. The filtrate and the washings are concentrated to about 10 or 15 cc., cooled, and then mixed with 5 cc. of concentrated sulphuric acid (specific gravity 1.84) and heated until copious fumes of sulphuric acid are evolved. In the absence of more iron than 0.025 in 100,000, acetic acid and ammonia are added directly. The mixture is next boiled and filtered, all the iron, dehydrated silica, and insoluble organic matter being left on the paper. The filtrate is then used for the colorimetric determination of lead by means of comparison of the shade produced by the addition of hydrogen sulphide solution with a set of standards containing known amounts of lead.

With more than 0.025 iron in 100,000, the process is somewhat different: the lead sulphate is washed into a beaker with alcohol and

[1] Chemiker-Zeitung, 1898, XXII., p. 225.
[2] Journal de pharmacie et de chemie, 1898, No. 7, p. 72.
[3] Loco citato, p. 582.

water, and allowed to stand over night, and then filtered off and washed with 50 per cent. alcohol until free from iron. The lead sulphate is then dissolved by boiling the filter with ammonium acetate in a porcelain dish. Experience has demonstrated that this process is extremely accurate and reliable.

The author finds the following process simple, rapid, and accurate. Evaporate 3,000–4,000 cc. of water to about 15–20 cc. in a porcelain dish; add, little by little, and with gentle heat, sufficient dilute hydrochloric acid to dissolve any incrustation of salts on the sides and bottom, and to give a *slight* acid reaction; then add 5–10 cc. of hydrogen sulphide water of good strength. Any lead present is precipitated in a very fine state, but not so fine but that the entire amount can be collected on a Swedish filter. Wash twice, and then treat on the filter with boiling dilute nitric acid until the black deposit is wholly dissolved. Wash with hot water as long as the washings are acid, and add them to the nitric acid filtrate. Evaporate to dryness in the original dish, add distilled water, and again dry. Dissolve the residue in hot distilled water and make up to 50 cc. Take 5–10 cc. and dilute to about 80 cc. with distilled water in a glass comparison tube of 100 cc. capacity, add hydrogen sulphide water in sufficient amount, make up to 100 cc. with distilled water, and mix thoroughly by inverting the tube a number of times. Compare the depth of color with those of a series of tubes containing known amounts of lead as lead nitrate, treated with hydrogen sulphide in the same way.

The standard solution is made by dissolving 0.160 gram of pure lead nitrate in 1 liter of distilled water: 1 cc. represents 0.1 milligram of lead. A convenient scale is made with 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 cc. of the solution in 100 cc. If the hydrogen sulphide water is added after diluting to about 80 cc., the result is a series of sufficiently clear standards showing sharp and regular stages of color. If the reagent is added before the lead salt has been sufficiently diluted, the standards are very turbid, and are lacking in the very essential gradation of color.

Should the depth of color obtained in the preliminary test be greater than that given by No. 10, a smaller amount should be taken and the experiment repeated. Should the color be very faint, the whole of the remainder may be treated and compared. From the result obtained by matching the colors, the amount of lead in parts per 100,000 is easily calculated.

EXAMPLE.—Ten cc. treated as above gave a color reaction midway between standards 6 and 7; hence, one-fifth of the whole contains 0.65 milligram of lead, and the entire amount contains 3.25 milligrams. The amount of water concentrated was 3 liters. Hence 1 liter of water contains 1.08 milligrams, and 100 cc., or 100,000 milligrams of water, contain 0.108 milligram of lead.

Detection of Zinc.—One is reasonably safe in assuming that water which has been in contact with galvanized iron will show the presence of zinc. This may be determined quantitatively by evaporating a

quantity of water to a small bulk, heating the latter with a sufficient amount of dilute hydrochloric acid in order to take up any oxide or carbonate, and then proceeding to the precipitation of the sulphide after making alkaline with ammonia. For qualitative purposes, a volume of water is made slightly alkaline with ammonia, boiled, and filtered. The addition of a few drops of test-solution of potassium ferrocyanide to the filtrate will, in the presence of traces of zinc, cause a white precipitate, or at least an opalescence, which, however, may not be distinct within a half hour.

Detection of Tin.—Although, so far as known, tin in water has no sanitary significance, it sometimes is desirable to ascertain its presence in water and in other substances. For rapid testing for this metal, the method recommended by C. Deniges[1] may be employed. This depends upon the fact that stannous compounds cause a reddish-violet color with nitrate of brucine. The brucine solution is made by dissolving 0.5 gram of brucine in 5 cc. of nitric acid, diluting to 250 cc. with distilled water, boiling for fifteen minutes, and, after cooling, making up the volume to 250 cc. again. The water is evaporated to dryness with a little hydrochloric acid. The residue is dissolved in a very little water, and to it is added 1 cc. of the brucine solution. If so little as the twentieth part of a milligram of tin is present, the color change will be distinctly shown even in the presence of iron and copper.

Detection and Determination of Iron.—This very common and frequently troublesome constituent of water is detected very easily by concentrating a sufficient volume of the sample to a small bulk, converting the iron present from the ferrous to the ferric form by boiling with a little nitric acid, and adding a few drops of a solution of potassium sulphocyanate, which causes a deep-red coloration. By means of a scale made with known amounts of ferric iron treated with the same volume of test-solution, the amount of iron may be determined quite accurately. A standard solution of iron may be made by dissolving 0.10 gram of pure metallic iron in aqua regia and diluting to 1 liter with distilled water: 1 cc. represents 0.10 milligram of iron. The comparison scale is made by diluting progressively increasing volumes with distilled water up to nearly 100 cc., adding a few cc. of a 5 per cent. solution of potassium sulphocyanate, and then making up to 100 cc.

For other determinations of a strictly technic character, the reader is referred to the many excellent treatises bearing on the subject.

Inferences as to Character of Water from the Results of Sanitary Chemical Analysis.

It is impossible to fix any absolute standards by which to pass upon the potability of water without reference to its origin, for surface-waters cannot be judged by the same standards as ground-waters, and,

[1] Revue Internationale des Falsifications, VIII., p. 98.

moreover, those which apply to waters of either class from one locality may be wholly inapplicable to those from another. A surface-water, for instance, may without prejudice yield an amount of albuminoid ammonia which would be most suspicious in the case of a ground-water; while the latter may contain, under some circumstances, an amount of free ammonia inconsistent with purity in the case of the former. Again, an amount of chlorine which in a water from near the sea would be normal, would indicate in another from far inland the presence of sewage matters.

Ammonia may be expected in some amount in any water; it is characteristic of decomposition of organic nitrogenous matter of innocent character as well as of sewage, and it may be present in considerable amounts in both normal and polluted waters. Furthermore, it may be present in higher amounts in water from an uncontaminated deep-bored well or in stored rain, than in polluted water that has undergone chemical change. Albuminoid ammonia may be yielded in equal amounts by a water contaminated by sewage, and by one quite free from it, but rich in dissolved vegetable matter derived from leaves. Richness in mineral matter may be present equally in normal and polluted waters. A pure water may be rich in nitrates, while a sewage-water may have lost them by reduction. Either may be colored or not, clear or turbid, and odorous or odorless.

There is one constituent, however, the presence of which in more than measurable quantity is a tolerably sure indication of pollution, that is to say, the nitrites; but their absence is not a guarantee of purity, for in grossly polluted waters they may be wholly wanting. In general, however, it may be set down as a safe rule, that nitrites and high free ammonia together mean recent pollution; occurring continuously, they indicate constant pollution; and, with chlorine fairly above the local normal, ordinary sewage contamination. High ammonia with nitrites, but with no marked increase in chlorine, may indicate contamination by matters from manured farming land.

The results obtained in the chemical analysis of a specimen of water are often quite sufficient for the formation of an opinion of its suitability or unfitness for general domestic purposes, but more often a knowledge of the source and the surroundings thereof is necessary for their intelligent interpretation. They may be such as to indicate that, whatever its source, the water which yielded them is very good or distinctly bad; but, on the other hand, they may be such that full knowledge of all the facts is imperatively necessary for the formation of a correct judgment. A water yielding the following results, for instance, may unhesitatingly be pronounced to be of undoubted purity so far as chemistry can determine, quite irrespective of source (the figures express parts per 100,000):

Free ammonia	0.0002
Albuminoid ammonia	0.0018
Nitrogen as nitrates	0.0240
Nitrogen as nitrites	0.0000

Chlorine	0.07
Volatile residue	1.25
Fixed residue	1.60
Total residue	2.85
Hardness	1.00

Appearance, clear and bright.
Color, absent.
Odor, absent.
Changes observed on ignition of residue, no blackening.

In this case the figures indicate almost total absence of organic matters, and but slight amounts of mineral constituents. There is no suggestion of contamination of any kind, and the only conclusion that can be drawn is that the water is pure and soft, and suitable for all domestic purposes.

On the other hand, the following results may, in the same way, be sufficient for unqualified condemnation.

Free ammonia	0.4750
Albuminoid ammonia	0.0585
Nitrogen as nitrates	4.600
Nitrogen as nitrites	0.054
Chlorine	4.27
Volatile residue	11.10
Fixed residue	23.30
Total residue	34.40
Hardness	14.00

Appearance, clear and bright.
Color, absent.
Odor, foul after heating.
Changes observed on ignition of residue, slight blackening.

These results, which are actual ones obtained from a specimen sent to the author with no statement of origin, warranted a report of gross pollution, regardless of source, for the presence of sewage matters was undeniable, and under no circumstances of geographical location could any other report be made. Inquiry concerning the origin of the water brought the information that the well from which it came was located at no great distance from a leaching cesspool, and was used only when the usual source of supply, a spring, ran dry. Repeated attacks of illness of no great seriousness had been noticed whenever, during the preceding three years, this water had been used.

These two waters may serve as good examples of undoubted purity and extensive pollution. Both are ground-waters, and, what is not without interest, they came from one and the same small inland town.

Such results as the above require no long consideration—they speak for themselves. But it very commonly happens that even a single ingredient may cause suspicion of sewage pollution to arise when information as to the location of the supply is withheld. Thus, the amount of chlorine may be very considerably higher than the lowest normal commonly observed inland, and yet well under the amount which excites no adverse comment in a water from the coast. Thus, 3.85 parts in a well-water from an island in Boston Harbor, and 1.35 in another from the borders of Long Island Sound, may be regarded

as fairly low; while if found in springs in the Green Mountain range, they would be most abnormally high and of much significance.

Again, such an amount might come in connection with fair yields of the ammonias, and then under one class of conditions the organic matters would appear to be of vegetable origin and in another to be a part of sewage.

It is also impossible to draw sharp dividing lines between small, considerable, and high amounts of the ammonias; but, in general terms, it may be stated that up to 0.005 or 0.006 part per 100,000 may be regarded as low, from thereabouts to 0.015 or 0.020 as considerable, and beyond as high. Measurable amounts of nitrites are most significant, while nitrates may run up to several whole parts per 100,000. Thus, it may readily be understood that, in the majority of cases, the results should be considered in conjunction with all material facts connected with source, surroundings, and opportunity for receiving pollution.

Bacteriological Examination of Water.

The bacteriological analysis of water may be divided into quantitative and qualitative determinations. The former is commonly extended over long periods, and has for its object the determination of the normal bacterial content of a given water supply and the observance of any unusual variation therefrom; while the latter is pursued for the purpose of determining the nature of the organisms, and, more particularly, whether they are such as are to be found in the excreta of the body. The finding of such does not mean necessarily that the use of the water will inevitably produce disease, but it indicates the possibility and probability that water containing non-pathogenic organisms from this source may, if not to-day, to-morrow, or later, become infected with others from the same source, capable of acting as the exciting cause of grave disaster.

As is the case with chemical analysis, it is impossible to fix any standard of safety based on the mere amount expressed by the quantitative results, since it is the nature and not the amount of the contaminating matters which determines the question of potability. But sudden deviations from the seasonal normal suggest unusual access of contamination, and serve as warnings of possible danger.

The isolation and systematic study of the various species of bacteria in a given water to determine whether or not they may be pathogenic, involve much labor and an intimate knowledge of bacteriological technic which can be acquired only by thorough training in a bacteriological laboratory. Familiarity with the methods of preparing culture media and making cultures, of isolating species and studying their characteristics, is, therefore, a necessary qualification for the pursuit of bacteriological examination of water, and anything more than a brief outline of special methods employed in this par-

ticular field of research would be beyond the scope of a work of this character.

Collection of Samples.—In taking samples, it is, of course, necessary to observe the most rigid precautions against the introduction of extraneous organisms. All vessels should, therefore, be absolutely clean and sterile. Collection may be made either in small bulb tubes, drawn out into a point and sealed by closure in a lamp flame, or in bottles of about 200 cc. capacity with ground stoppers. The bulbs are made easily by anybody who has had ordinary experience in qualitative analysis. By the application of the heat of a lamp immediately before sealing, or by vaporizing a drop of contained water by the same means and sealing just as the last of the steam is escaping, they will contain but little air, and when used are filled easily through the influence of the partial vacuum.

In taking the sample, the point is introduced below the surface of the water and then broken off with sterile forceps. The bulb is filled partly almost immediately, and then the broken point is sealed as before by the application of heat from a gas flame or alcohol lamp. If bottles are used, they should first be washed on the outside in the water to be sampled, and then plunged beneath the surface. The stoppers are then withdrawn, and, when filling is completed, they are replaced.

If any considerable time must elapse before cultures can be made, the samples should be packed in ice, in order to retard multiplication of the contained bacteria; and since very low temperatures have no harmful influence on the vitality of the organisms, the addition of a small amount of salt to the ice may be of advantage, although freezing should not be permitted, on account of the danger of bursting the containers.

Planting the Samples.—If possible, the planting should be accomplished on the spot, on account of the multiplication which is inevitable with delay. If this is not possible, no greater delay should be permitted than is absolutely necessary.

For qualitative determinations, two sets of plates should be made: one on gelatin, to be kept at 18°–22° C.; and one on agar-agar, to be incubated at 37°–38° C. When working on a water of unknown character hitherto unexamined, different amounts of the sample—1, 2, 3, and more drops—should be used, since one can have no definite idea of its bacterial richness.

In quantitative work, the amounts taken should be measured with the greatest accuracy, especially when preliminary determinations have shown such a number of organisms as to make great dilution with sterile water necessary, for any departure from absolute accuracy introduces an error which will be multiplied according to the degree of dilution.

When bulb tubes are used, their contents are expelled with the aid of gentle heat, which causes the small amount of contained air to expand and force the liquid through the stem, which is broken at the

point by pressure from sterile forceps. The expelled water is received in a sterile tube, from which it may be withdrawn in a sterile graduated pipette.

Quantitative Determination.—The value of quantitative determinations lies in the comparisons which one is enabled to make from a series of periodical examinations of the same water, for the information to be derived from a single examination has very limited utility. By means of periodical counts, one is enabled to form an idea of the conditions normally present under different circumstances, and to note at once any disturbing influence. Quantitative determinations are of special value in noting changes in the efficiency of sand filtration of public supplies.

Knowing from preliminary tests or from past experience how much water should be taken for each plate or roll, and the degree of dilution necessary, two sets are made, one on gelatin and one on agar-agar, and the growths allowed to develop. Gelatin cultures are kept at 18°–22° C.; the other are incubated at 37°–38° C. The lower of these two ranges of temperature is much more favorable to the multiplication of ordinary water bacteria than the higher, and consequently it will be found that the colonies developing on the gelatin will be decidedly more numerous than those on the agar-agar. In expressing results, therefore, mention should be made of the culture medium employed; and in making comparisons of one day's results with those of another, the importance of limiting them to figures obtained under like conditions of culture medium and temperature is too obvious to need farther mention.

The counting of the colonies should be undertaken always at the expiration of fixed intervals of time, since more and more develop from day to day, particularly on agar-agar. For assistance in counting, one may employ the well-known Wolffhügel apparatus, or one of the several modifications thereof; or, what is more simple, may have the bottoms of Petri dishes or under surfaces of the ordinary glass plates, whichever are used, ruled off in square centimeters by means of a writing diamond. The entire number of colonies on the plate may be counted, or those falling within a certain number of squares may be averaged and the result multiplied by the whole number of spaces covered by the culture medium.

Drs. W. Hesse and Niedner[1] have proposed a method for quantitative determinations which obviates the use of nutrient gelatin and all the attendant disadvantage due to liquefying bacteria. Their most important recommendations are as follows:

The amount of water planted per plate should be such as will produce no more colonies than may easily and accurately be counted; that is to say, not more than a hundred. At least five plates should be prepared, and if these yield results fairly in agreement, their average should be taken; but if any plate gives figures more than 100 per cent. removed from the mean, it should be discarded. These should

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXIX., p. 454.

be kept at room temperature and in the dark as long as new colonies develop, that is, for two to three weeks, at the end of which time one may make counts which will have some claim to accuracy. On account of the evaporation that occurs during this time, it is necessary to use for each plate at least 10 cc. of culture medium. The most suitable medium is made with 1.25 parts of agar-agar, 0.75 part of albumose, and 98 parts of distilled water. Gelatin should not be used, on account of the rapidity with which plates made with it become useless on account of the liquefying colonies, which obstruct some growths and dissolve and wash others away. The medium above described possesses the advantage that it needs no addition of acid or alkali.

Qualitative Determination.—The chief interest in qualitative examination of drinking-water lies in the solution of the question whether or not intestinal bacteria are present. Plates may be prepared and preserved in the same manner as for quantitative work, except that the amount of water planted needs no accurate measurement, but, on account of the usual great preponderance of the common harmless bacteria, it is rarely the case that one can isolate the pathogenic varieties without recourse to special methods which favor their growth and at the same time kill off the others. One such method consists in incubating the sample with bouillon for thirty-six to forty-eight hours at 37°–38° C., and then preparing plates in the usual way. The common bacteria are in this way subjected to conditions unfavorable to their growth and vitality, while multiplication of the pathogenic varieties is promoted. Another method, depending upon the resistance of the typhoid organism and *B. coli communis* to the action of dilute carbolic and hydrochloric acids and the powerful influence of these agents on the common water bacteria, consists in incubating a few drops of the sample in 10 cc. of bouillon containing a few drops of a solution of 5 parts of phenol and 4 of hydrochloric acid in 100 of distilled water. The bouillon is incubated first with the phenol mixture for twenty-four hours at 37° C., and then receives the sample. After farther incubation for twenty-four hours or longer, plates are made in the usual way and the resulting growths systematically studied. Still another process is that of Professor Theobald Smith,[1] who recommends the addition of a few drops of the water to bouillon containing 2 per cent. of glucose, and incubating in fermentation tubes at 37°–38° C. for thirty-six to forty-eight hours, at the end of which time, if gas has accumulated in the end of the tubes, plates are prepared in the usual way. By this process it is possible to secure pure cultures of the intestinal bacteria.

For the detection of *B. coli* in water supplies, the use of neutral-red has been proposed. Rothberger,[2] in 1898, found that this color is reduced by this organism, but not by *B. typhosus*, and is changed to canary-yellow with green fluorescence. Later, he discovered that certain anaërobes have the same power (*B. tetani*, *B. œdematis maligni*, *B. anthracis symptomatici*). The majority of the aërobic pathogenic bacteria

[1] American Journal of the Medical Sciences, September, 1895.

[2] Centralblatt für Bakteriologie, etc., XXIV., p. 513.

have been tested with negative results. Scheffler[1] found the reaction to be constant in his investigation of a large number of races of *B. coli*, and concluded that organisms which give negative results may be excluded from the coli group.

Makgill[2] found that *B. tetani* and *B. œdematis maligni* produce the same effect as *B. coli* in glucose-agar even when the surface of the medium is exposed to air, but in bouillon the anaërobes produce the reaction only when oxygen is excluded. He discovered that *B. mesentericus* changes the red to a dull orange both in bouillon and in glucose-agar. His experiments thus far seem to indicate that a water producing a typical canary-yellow in neutral-red media, within forty-eight hours in bouillon, and accompanied in glucose-agar by green fluorescence and gas formation, may be considered to contain *B. coli*. He finds that 1 to 5 organisms per cc. will produce the reaction in bouillon within twenty-four hours, and large numbers within twelve hours. He concludes that neutral-red affords a rapid and very delicate test of the presence of *B. coli;* that, using varying quantities of water, a rough estimate may be obtained of the number present; that a negative result with a fair sample is evidence of their absence; and that farther investigation is needed to show that the reaction is positive evidence of their presence, although in his experiments it was present whenever the reaction occurred.

Savage,[3] using glucose media (broth or agar containing 0.5 per cent. of glucose), found that agar gives the best results. He warns against employing an excess of neutral-red, for it may not be reduced. His best results were from 0.1 cc. of an 0.5 per cent. aqueous solution of Grübler's neutral-red added to 10 cc. of broth or agar. From the results of an extensive series of experiments, he concludes that a positive reaction is not absolutely diagnostic of *B. coli*, but in the vast majority of cases points to its presence; that a negative reaction does not exclude it, but makes its presence highly improbable; and that the test is very easy to apply, and of great value in the routine examination of water.

For the detection of the cholera organism, Koch recommends incubating 100 cc. of the suspected water with 1 gram each of sodium chloride and peptone at 37° C., and preparing therefrom at intervals of ten to twenty hours agar-agar plates, from which, if colonies develop, other plantings may be made for systematic investigation. For the detection of the cholera organism in small numbers in the presence of water bacteria, Dr. Arens[4] has found caustic potash of assistance, and recommends incubating 175 cc. of water with 25 cc. of pancreas bouillon containing from 0.10 to 0.16 gram of the alkali, by means of which the growth of the organism is favored. Dr. Aufrecht,[5] working on similar lines, found that the development of the organism is favored by gelatin containing 1 per cent. of caustic soda.

[1] Centralblatt für Bakteriologie, etc., XXVIII., p. 199.
[2] Journal of Hygiene, October, 1901, p. 430. [3] Ibidem, p. 437.
[4] Münchener medicinische Wochenschrift, March 7, 1893.
[5] Centralblatt für Bakteriologie und Parasitenkunde, March 23, 1893.

Comparative Value of Chemical and Bacteriological Analysis of Drinking-water.

As the science of bacteriology began to develop and take the position to which its importance gave it a title, its disciples conceived a strong prejudice against and contempt for any opinion as to the potability of a particular water based upon chemical analysis, maintaining, quite correctly, that minute amounts of ammonia, albuminoid ammonia, and chlorine are incapable of acting as the exciting cause of infective disease, and that not these substances, but only specific organisms not demonstrable by chemical processes, can so act. It must be conceded that, for a time prior to the discovery of the nature of the infective agents, the importance of the results of chemical analysis was grossly exaggerated, and that arbitrary standards, such as were established by the Rivers Pollution Commissioners, upon which conclusions were based, have, in the light of farther experience, been abandoned as absurd and untrustworthy. But it must also be conceded, even by those who were most caustic in their criticism, that chemistry is to-day equal, if not superior, to bacteriology in indicating possible danger from the use of water exposed to contaminating influences.

In the earlier days, much capital was made by bacteriologists of the fact that a sample of water, inoculated with a culture of the bacillus of typhoid fever, was reported by a chemist of high standing as of great purity and eminently suitable for domestic purposes. Such a test, however, is unworthy of the slightest consideration, since under natural conditions a water showing a high degree of chemical purity is not likely to be infected with a pure culture of a pathogenic organism, and the submission of a pure water so treated is a mere trap, the setting of which is no more praiseworthy than would be the sending of a sterile solution of cyanide of potassium or of sulphate of strychnine to a bacteriologist with a request for an opinion from the standpoint of his specialty as to its desirability as a beverage.

Chemical analysis can show the presence of organic and mineral impurity such as accompanies infectious matters from the intestine and bladder. It cannot give grounds for a positive assertion that the use of a water thus polluted will inevitably cause disease, but it can and does serve to point out possible danger. It can detect the presence of sewage matters, and while it cannot prove the presence of infectious material therein, it can at least point out that the occurrence of typhoid fever in the community furnishing the sewage is likely to be followed by other cases of the disease in the community which uses the polluted water. It cannot distinguish typhoid pollution from any other excremental contamination, since a healthy body yields the same chemical substances as one that is diseased. In the case of waters containing no evidence of contamination, it can supply the basis of an opinion as to safety, but it cannot furnish any guaranty that the condition is permanent.

Bacteriological analysis differentiates between pathogenic and non-pathogenic contamination, but it is only rarely that it serves to point out danger in advance. Even when an outbreak of typhoid fever has occurred and attention is drawn thereby to the condition of the water supply, the results of bacteriological examination are generally negative. The reason for this is twofold. In the first place, the examination for the detection of the specific organism is not ordinarily begun until attention is drawn to its necessity by an outbreak of the disease, which does not appear until about two weeks from the time contamination has occurred. Unless the contamination is continuous, by the time the examination is instituted, the polluting materials have either passed on or the specific organisms have perished. In the second place, even although they are present, with our present methods it is not an easy matter to isolate them, and we can determine in most cases only the probability of their presence.

It should be borne in mind that the organisms are particulate bodies in suspension in great dilution, and that their distribution is not homogeneous as is the case with substances in solution, and that, therefore, the amount of water taken for planting plates may not contain them. But in the unsuccessful search, it is not uncommon to find *B. coli communis*, and where this organism lurks, the other may have been present.

As a rule, bacteriological search for the typhoid bacillus has given negative results. Laws and Andrews failed to find it in the sewage of London, although it must have been present; and they had but slight success in the examination of sewage from a hospital where forty cases of the disease were being treated. The reason for this may be that through absence of suitable food material and favorable temperature, and by reason of the antagonistic influence of the ordinary sewage bacteria, the typhoid bacilli had lost their vitality; or it may be that they were so diluted that the volumes used for planting failed, as a rule, to contain them. Examination of the water supposed to be concerned in the unusual outbreak at Maidstone yielded absolutely negative results, although no reasonable doubt can exist that at some time they had been present.

Professor Percy Frankland, who has had a large experience in dealing with micro-organisms in air and water, says:[1] "The detection of specific pathogenic bacteria in drinking-water is now known to be almost beyond the range of practical politics, and the search for such bacteria is, in general, only carried on in deference to the special request of the layman, the uninitiated, or the hopelessly ignorant, whilst it cannot be repeated often enough that any feeling of security which may be gathered from an unsuccessful search for pathogenic bacteria is wholly illusory and in the highest degree dangerous. . . . By far the most important service which has been rendered by bacteriology is the means which it affords of controlling the efficiency of filtration and other purification processes. The slightest irregularity or defect in the proc-

[1] Journal of the Sanitary Institute, October, 1899, p. 393.

ess of filtration is at once laid bare. Bacteriological purity of well-waters can also be satisfactorily controlled."

Professor W. H. Horrocks,[1] too, remarking on the fact that, if a considerable time has elapsed since the occurrence of pollution, the bacteriological detection of the same, especially when waters of great original purity are concerned, becomes more and more difficult, adds: "It is, therefore, evident that a bacteriological examination has its limits of usefulness, and a slavish adherence to it under all conditions, combined with neglect of the hints to be obtained by chemical means, may lead to a perfectly erroneous judgment. Still, there is one branch of hygienic study in which bacteriology must always reign supreme; it is now acknowledged on all sides that the working of sand filters for public water supplies cannot be properly kept under control except by appealing to bacteriological methods of examination."

A positive result, the first instance in which the organism isolated responded to every test, including growth on gelatin, potato, litmus milk, bouillon and glucose bouillon, agglutination, and Pfeiffer's test with animals, is recorded by Drs. Kübler and Neufeld.[2] In this case, the cause of the disease lay in the use of water from a well infected by the urine of a person sick with the disease. Four weeks from the time of the first examination when the bacillus was isolated, a second analysis was made, which yielded bacilli which responded to all the tests excepting Pfeiffer's, which exception was supposedly due to modified virulence. No colon bacilli were present either time.

A second instance is recorded by Fischer and Flatau,[3] who isolated the organism from a well-water in Rellingen. Similarly, a second attempt, made four weeks later, was unsuccessful.

From what has gone before, it may be said that neither chemical nor bacteriological analysis is infallible. Each has its uses, and each may be helped by the other. The value of either lies in the skill displayed in interpreting the results, and this requires as much knowledge as the making of the examination itself.

[1] Bacteriological Examination of Water, London, 1901, p. 3

[2] Zeitschrift für Hygiene und Infectionskrankheiten, XXXI. (1899), p. 133.

[3] Centralblatt für Bakteriologie, etc., XXIX. p. 329.

CHAPTER V.

HABITATIONS, SCHOOLS, ETC.

Section 1. GENERAL CONSIDERATIONS.

It is essential to health that the houses in which we dwell shall be built upon proper sites, free from dampness and organic pollution; they should be provided with adequate means for heating, ventilating, and lighting; they should be well supplied with water for general domestic purposes, and provided with a proper system of plumbing for the removal of sewage; they should be constructed with proper precautions against dampness from without or below. *Heating, ventilation, lighting,* and *plumbing* are considered below under their several headings.

Aspect.—It is commonly directed that habitations should be placed so as to face the south; but, unfortunately, one is not always in a position to be over-particular in the matter of points of the compass, and, indeed, there seems to be no particularly good reason why that side of the house in which is located the main entrance should face south and the others respectively north, east, and west. The southerly side of a hill is very much to be preferred to the northerly, because of the greater amount of sunlight and of protection against the cold winds from the north; but in a plain and elsewhere, whichever wall of the house faces south, there must be, if the structure be rectangular, one to the north. Far better is a location with the corners of the house pointing north and south, for in that case every window must receive some direct sunlight at some part of the day, whereas with sides facing directly north and south, the windows of the former receive no direct sunlight and the rooms are dull and cheerless. In large cities, aspect is commonly a minor consideration, the desirability of a house being determined mainly by other circumstances. In general, it may be said that, when possible, a house should be so situated as to insure an abundance of light and air with protection against the cold winds of winter.

Construction and Arrangement.—Consideration of building materials and the details of arrangement of rooms and division of floor-space are beyond the scope of a work of this nature, and it is necessary only to call attention to the importance of insuring dryness, light, and air, and such thoroughness of construction as shall not permit a too generous amount of natural ventilation with consequent waste of heat.

Of the very greatest importance is the character of the cellar, that part of the house which is most neglected during both construction and occupancy. Unless the site is one of unusual dryness, the cellar floor

should consist of a generous layer of cement impervious to moisture from below and to soil-air and its contamination, such as gas from leaking mains. The foundation walls should be tight and dry, and should contain in their upper part a sufficient number of windows of a size to admit an adequate supply of light.

The walls should be made as far as possible proof against wind and weather. In exposed positions, it may be that a clapboarded wall is far drier than one of brick, for the latter material, if very porous, is not uncommonly wet through by driving rain, and does not quickly become dry again. Sometimes it becomes necessary to cover an entire brick wall with a protective coating of paint, or even with a sheathing of tin plate. For protection against dampness and cold, external walls may be built with an intervening air space, which acts like that of a double window; the outer and inner faces of the wall are joined at intervals by bonding bricks or ties of various materials, including hard non-porous bricks, glazed bricks, and iron.

Roofs should be tight and protected against the backing up of water from melting snow and ice when the gutters are filled with ice. As a covering, slate is much to be preferred to shingles, though its initial cost is much greater; it is permanent in character, impermeable, and requires but little repairing, while shingles wear out in course of time, and, by taking up moisture, lead to rotting of the timbers beneath. Tin is tight and impermeable, but is very hot in summer. Tar and gravel are well suited to nearly flat roofs, the gravel protecting the tar from the action of the sun, and the combination being very durable.

Care of Habitations.—The proper care of a house and its surroundings is a subject that can hardly be taught; with many, it is a natural instinct; with more, very little is required to satisfy the understanding of the term. A large class distribute house sanitation with an uneven hand, insisting upon the perfection of care of those parts which they inhabit and in which the outside world is received, and neglecting those where filth is most likely to accumulate, but to which, perhaps, the general overseeing eye never penetrates. In a way, the most important parts of a house are the cellar and the kitchen, and these should receive more careful attention than the drawing-room, where, presumably, organic filth can hardly gain access in appreciable amounts. The otherwise careful housekeeper, to whom a burnt match on the hearth of an open fire is an abomination, will, perhaps, view with placid face the boxes, baskets, and even barrels of rotten fruits and vegetables, dirty cans, and other refuse brought to the surface from the cellar once each year at the time given over to "spring cleaning." The perfectly kept house knows no cleaning seasons.

SCHOOLS.

Schools, even more than habitations, require the best of situations with reference to light and air. Windows should be large and numerous, and, according to the estimates of different authorities, their com-

bined area should equal from a tenth to a fourth of the total floor area. In the arrangement of school furniture, the main consideration lies in the direction of the light. The desks are placed best so that the light comes from the left of the pupils; coming from the right, it casts annoying shadows of pen or pencil in exercises requiring writing; cross-lighting may cause still greater annoyance by casting double shadows. Light from the front is exceedingly trying, as may readily be appreciated by attempting to read a clock placed between two windows; from behind, it casts shadows of the body upon the work on the desk.

Cloak rooms should be spacious and well ventilated, and provided with ample hanging facilities permitting sufficient space between the individual garments.

Water-closets and urinals demand more than usual care, for children are prone to carelessness in their use; and since they are commonly placed in the basement, they are very likely, if not kept in scrupulously clean condition, to pollute the air of the rooms above.

School Furniture.—School furniture is well known to be one of the most important influences in the development of lateral curvature, and much careful study has been pursued in improving its construction. Desks and chairs should not be supplied with reference to age, but according to the size of children, and should be adjustable to each child. Common faults of chairs include improper shape of back, improper height, too great depth or breadth of seat, too much slope from front to back, and improper horizontal distance from the desk. Common faults of desks include insufficient or too great height, and improper slope of the surface.

Chairs should be of such a height that when the leg and thigh form a right angle the foot shall be squarely on the floor. If too high, the child cannot touch the floor, and fails to obtain the needed assistance from the feet and legs for the maintenance of an upright position; if too low, the position is cramped and awkward and the child is forced to extend the legs in one direction or another, and to contort the body accordingly. The seat should be sufficiently wide to support both thighs comfortably, but not so wide as to permit the assumption of bad postures in which the back is not well supported. It should not be too deep from front to back, since then proper attitude is impossible. It should slope very slightly from front to back, or be made slightly concave, in order that the tendency to slip forward may be counteracted. The back should be curved forward, so as to support the child's back, and to be comfortable in whatever legitimate attitude he may assume, for he requires changes in position for the relief of downward pressure and strain of muscle and ligaments, since any attitude long maintained results in fatigue. With chairs of the best form of construction, faulty attitudes are less comfortable than proper ones.

Desks should be of such a height that the forearms of the child may be rested without causing, on the one hand, stooping, or, on the other, raising of the shoulder and curving the spine. If too high for the child, the work is brought too near, and causes straining of the eyes.

The top should have a proper slope downward of from ten to twenty degrees, and its edge should project slightly over the forward edge of the chair, so that the body and head may not be inclined forward too far.

Proper height of seats and desks and correct horizontal distance between the two are attained by the adoption of adjustable furniture, of which there are many varieties.

Blackboards should be dull black, and never shiny, for if they are shiny they reflect light, and what is written thereon is difficult to read from certain points in the room. They should be kept well cleaned, in order that the contrast with the chalk shall be sharp. The chalk should be white or yellow; blue, green, and red chalk marks are much more difficult to read. Blackboards should never be placed between windows, on account of glare. Copying from blackboards is very trying to the eyes, on account of the constant necessary change of focus.

Legislation Concerning Schools.—Many of our States have enacted laws providing for school sanitation in several particulars. Seventeen require expert examination of plans for projected buildings. Sixteen provide for fire-escapes and other protection from fire. A number provide for proper ventilation, but only two, Massachusetts and Connecticut, have established a standard and require its enforcement. Kentucky alone provides standards for lighting, for floor space and air space, for proper seating, and for water supply. About one-third of the States and Territories compel vaccination, and one-fourth provide safeguards in the matter of contagious diseases in general.

Section 2. VENTILATION AND HEATING.

We have seen how necessary it is to life that the CO_2 given off by the blood in the lungs to the inspired air shall be discharged continuously from the body, and we know that whatever other effects the impurities of vitiated air may produce, the effect of undue CO_2 in the air is to interfere with the function of respiration. Therefore, it follows that the air which we breathe should be as free as possible from the impurities which we continually discharge into it, and that this condition can be obtained only by constant dilution of them by a constant supply of fresh air. In the open air, this dilution goes on without artificial assistance and requires no consideration; but in confined spaces, we have to a certain extent a reproduction of the conditions that obtain in the lung; namely, the presence of a volume of vitiated air, separated from the purer surrounding air, and requiring to be discharged and replaced. In other words, the air in the first confined space, the lung, is discharged into the second confined space, the room, and thence must be removed to the outside and replaced by an equal amount of normal air. The constant dilution and removal of impurities due to the necessities of life, so that their amount shall be so small as to be harmless, are the function of ventilation, which may be regarded as the respiration of a building.

It is, of course, not to be expected that the air of an inhabited room can under the usual conditions be maintained in a state of purity like that of the outdoor air, even though but one candle or one person be present to exchange carbon dioxide and water for oxygen, but the impurities can be reduced to a minimum by the introduction of a proper amount of fresh air. What shall be considered a proper amount of continuous air supply depends upon what we adopt as a limit of permissible impurity, measured by the amount of CO_2 present.

For the maintenance of a fair degree of vigor and stability through proper oxidation of the blood and dilution of the effete matters discharged, and for the maintenance of the fullest and most perfect functional activity, one requires respectively about 30 and 50 cubic feet of air per minute. Less than 30 will inevitably produce impaired vitality; more than 50 can be productive of no gain in improvement, so far as the effects of the ordinary vitiating matters are concerned. At the latter rate, then, an hourly supply of 3,000 cubic feet is necessary for the proper dilution of the respired air of each individual present in a confined space. Thus, a room of 3,000 cubic feet capacity, inhabited by one person, should receive its full capacity of fresh air once every hour. But this renewal should be a continuous process, so as to prevent the accumulation of impurities which would occur if the air were replaced simply in bulk by an hourly aëration by opening windows for the requisite few minutes. Nor should it be supposed that even with constant fresh supply the air of the room can have the same composition as that which enters from without, for the impurities of each respiration are not removed in separate, distinct lots, but are mingled in the general bulk. If the occupant's head were in a conduit bringing the constant supply of fresh air and carrying away the products of respiration, no such amount of air would be necessary, and no contamination of the general supply would occur. Under ordinary circumstances, with an hourly supply of 3,000 cubic feet per capita, the amount of CO_2 will not range above 6 or 7 volumes in 10,000, and any system of ventilation that will keep it down to this may be called good.

Other impurities than those of respiration are to be considered in all questions of ventilation. The influence of burning illuminating material on the composition of air is very great, both as to the consumption of oxygen and the production of CO_2 and other impurities, and it is not insignificant in its relation to the temperature. The impurities from 1 cubic foot of ordinary illuminating gas are such in amount as to require, according to various estimates, from 500 to 1,800 cubic feet of air for their proper dilution. They include not only carbon dioxide and water, but carbon monoxide, sulphur acids, nitrogen acids, marsh gas, ammonia compounds, unconsumed carbon, and other matters. Different forms of burners consume different amounts of gas to produce the same illumination; ordinarily from 3 to 6 cubic feet are used per hour, requiring 1,500 to 10,000 cubic feet of air-supply for proper dilution of the impurities produced by each burner. Therefore, on

both hygienic and economic grounds, the burner which produces the maximum of light from the minimum of gas is the best for use, it being understood that a given volume of gas will yield the same amount of impurities, whatever the burner employed.

The impurities from candles and lamps are less in number and variety, but, measured by their comparative illuminating power, they are larger in amount than from gas. For example, the combustion of an amount of candle or kerosene oil necessary to produce the same intensity of light as 1 cubic foot of gas will produce from 40 to 160 per cent. more impurities, and requires, therefore, proportionately more air for their proper dilution.

The subject of ventilation, involving, as it does, the continuous introduction of pure air to displace that which has become vitiated by whatever cause or heated to such a degree as to be inconsistent with comfort; having to deal with buildings and rooms of various sizes, designed for different uses; and, as it is chiefly in the colder months that its importance is greatest, being intimately connected with the problems and cost of heating, is a very complex one which will not permit the adoption of inflexible rules applicable to all cases.

Amount of Space Required for Good Ventilation.

If it be agreed that for the most perfect results an adult requires an hourly supply of 3,000 cubic feet for the removal of his own effete matters, to say nothing of the accessory impurity dependent upon illumination, the next question is as to the amount of cubic space necessary per capita, that is to say, through how small a space that amount of air can be drawn hourly without disagreeably perceptible draughts. The sensation of draught is governed very largely by the temperature of the moving air, a cold slowly moving current being more perceptible than a warm one moving at a greater rate of speed. Draughts which are productive of discomfort are more dangerous than the ordinary vitiation of the air, and, therefore, complete ventilation with draughts is worse than partial ventilation without draughts.

It has been shown by Pettenkofer that, with the aid of delicate apparatus and mechanical power, about 2,500 cubic feet can be passed without draughts through a space of 424 cubic feet in an hour; that is to say, through a room 8 feet square and 6.5 high, the air can be renewed six times.

The minimum space within which one can receive, under artificial conditions, six complete changes of air in one hour is, therefore, 424 cubic feet; but in order to get 3,000 cubic feet in one hour, the air would have to be changed seven times, and so the required minimum space would be 500 cubic feet. In large spaces, however, it is possible to obtain more frequent changes without danger from draughts. Thus, in a hall 40 by 20 by 15 feet, 40 persons may be supplied with 3,000 cubic feet each per hour, and each one will have 300 cubic feet of air

space. Therefore, in dealing with large spaces, we may assume 300 cubic feet per capita rather than 500.

In the ventilation of small spaces, there is, in addition to the possibility and danger of draughts, the grave difficulty that the inlets and outlets are necessarily so near together that much of the air will pass directly from the one to the other without having mingled with the main body of air, and without, therefore, doing the slightest service in diluting the impurities present. In large air spaces, this objection does not apply with equal force, for the opportunity for diffusion is greater, the larger the space, although, of course, here, too, the inlets and outlets may be so placed as to favor the formation of direct currents.

In the ventilation of large spaces in which large numbers of people gather, as churches, theatres, schools, and lecture-rooms, we are at once confronted by the fact that 300 cubic feet of space is a more liberal per capita allowance than is often practicable, and that this space is incompatible with a draughtless ventilation by the necessary air volume. If, then, the question be asked, how to provide the necessary amount, there is but one answer; namely, that it cannot be done. Fortunately, however, the danger from impure air is proportionate to the length of time of exposure, an occasional short time spent in a crowded room or public conveyance filled with bad air being less harmful than prolonged and habitual occupancy of a room in which the air is less vitiated, but yet not good.

In general, it may be said that the importance of ventilation varies with the particular air spaces; those which are used only at intervals and for short periods have much less need of it than those which are used uninterruptedly; those which are not crowded demand less than those that are; those used only for the moment need no consideration whatever, the natural forces at work at all times being sufficient for their needs.

To insist upon thorough ventilation of every part of a house at all times, as most amateur hygienists do, is to demand a needless waste of energy and money, for except in the warm months when the windows and doors are left freely open for the sake not alone of ventilation, but of general comfort, ventilation goes hand in hand with heating and divides the expense.

Nor can one successfully insist upon any rule that each person must have at least 1,000 cubic feet of air space with renewal of the contained air once in twenty minutes, for to do so is to urge in the case of the poor of large cities an impossibility, since space is costly, and, with ventilation to the proper extent, is beyond their means.

Natural Forces in Ventilation.

Before proceeding to the subject of systems of ventilation, we must consider the natural forces which are at work in the presence or absence of all schemes and systems. These forces are diffusion and gravity.

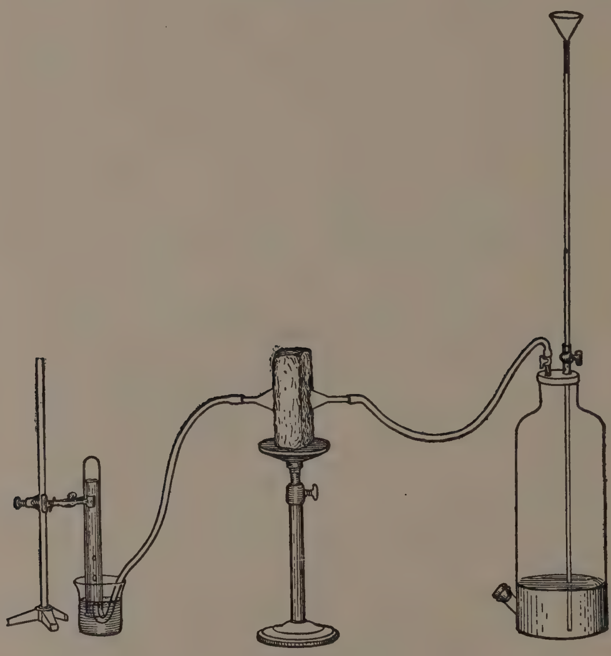
Diffusion and Gravity.—The rate at which gases diffuse is by no means the same for all, the lighter diffusing much more rapidly than the heavier. In fact, the rate varies inversely as the square roots of their densities. The province of diffusion in ventilation is limited to bringing the air to a condition of more or less complete homogeneity by causing the gaseous matters to become distributed throughout the mass; but in an inhabited room it can do but little toward keeping the air at its normal composition. By reason of the law governing the rate of diffusion, there must of necessity be a constant, though slow, removal of gaseous impurity into the external air, for wherever two gases are brought into contact, diffusion will occur, whether the meeting place be large spaces, as rooms, or small spaces, as pores in the plastering, bricks, mortar, stone or other material which forms the boundaries of that room. This force is, however, very inadequate, and can be of service only as an assistant to another. Moreover, it can affect only gaseous and not suspended matters.

Of vast importance, however, is the other force, that of gravity. Equal volumes of air at the same temperature and under the same pressure will have the same specific gravity; if the temperature of one of them be raised, it expands a definite amount for each degree, and thus has less specific gravity than the other the more it is heated. Being surrounded by air which is heavier than itself, it rises, or, more properly, is forced upward by the heavier air, which descends to occupy its place in the same way that a volume of light oil in a cylinder is forced upward when water is poured upon it. If, on the other hand, it is cooled, its volume contracts, its specific gravity is increased, and it sinks downward through the warmer lighter air below it. In this way, differences in temperature cause constant movements in bodies of air, and currents are established. In an inhabited room this force is always at work, for there must necessarily be some source of heat, even though it be only the body of the occupant. The air in contact with the body becomes heated, and is then displaced by the colder air about it; this in its turn is subjected to the same influences, and the whole of the contained air rises in temperature and is correspondingly expanded. As it becomes lighter than the surrounding air, the latter forces itself in and the original air out through all the available openings, and thus a certain amount of ventilation is accomplished.

Under the ordinary conditions of occupancy of a house or room, we have additional sources of heat in the combustion of fuel and illuminating materials, and no matter how imperfect the applied system of ventilation may be, and in spite of all efforts to exclude the external air, a very considerable amount of interchange of air is inevitable. It is only in a chamber that is to all intents and purposes hermetically sealed that no ventilation will occur when there is a difference between the internal and external temperatures. Heated air will escape through flues, through cracks around windows and doors, between the

boards of the floors and of the general structure, and even through the interstices of unpainted plastering and mortar, and through the pores of bricks. That a large volume of air will pass through cracks, needs no demonstration; the passage of air through bricks, plaster, and mortar may easily be shown. If to the opposite sides of a brick, we fasten by means of sealing wax two ordinary glass funnels, and then smear its entire exposed surface with a liberal coating of the same material, all of the external pores excepting those within the spaces covered by the funnels are made impervious to air. If now we connect by means of a rubber tube the funnel on one side with a bottle in which air can be compressed by means of water pressure, and by the same means the

Fig. 38.



Apparatus for demonstrating the permeability of bricks, etc., to air.

other funnel with an inverted test-tube filled with water, and apply pressure, the passage of air through the pores of the brick will be manifested in a few minutes by the escape of bubbles from the outlet tube upward through the water. (See Fig. 38.)

The passage of air through plastered walls is much impeded by wall paper, and may be totally prevented by oil paint and moisture.

Numerous experiments have proved that with varying differences between the internal and external temperatures, the air of a room or building will be renewed partly, wholly, or repeatedly every hour, even when efforts are made to prevent as far as possible the entrance

of the outside air. The results vary with the difference in conditions, the highest effects being produced when the temperature differences are wide, the opportunities for leakage great, and the external air in active motion. With perfect calm and equal temperature, the result will be *nil.*

Perflation and Aspiration.—Inequalities in outside temperatures give rise to the larger currents of air which we know as winds. These have a very great influence on ventilation both by their perflating action and by aspiration. The highest results of perflation are those obtained when obstacles to the free admission and exit of wind are removed, as, for instance, by opening windows in its path. The quickness and frequency of renewal of contained air by this means will necessarily depend

Fig. 39.

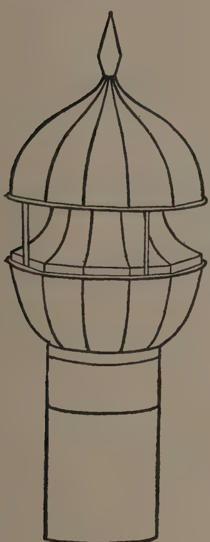
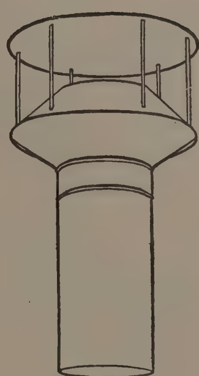
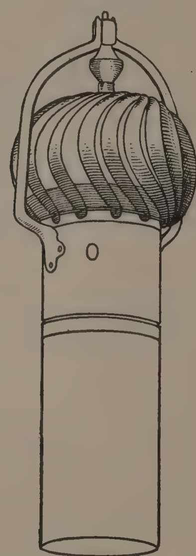


Fig. 40.



Common forms of stationary ventilating cowls.

Fig. 41.



Rotary cowl.

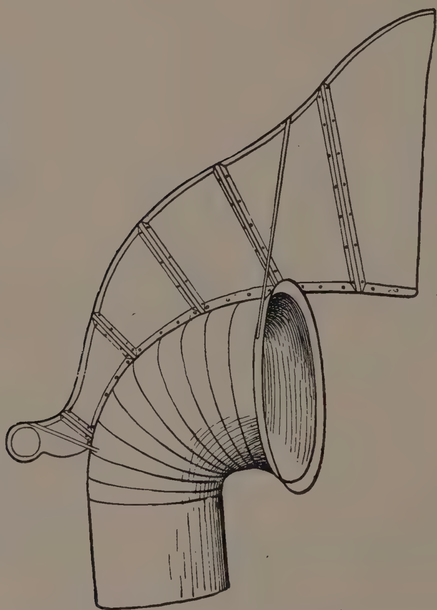
upon the size of the openings and the velocity and direction of the wind. The least effects are produced, whatever the velocity and direction, when the obstacles to entrance are greatest.

The aspirating influence of wind is shown by the upward currents produced in flues when the internal and external temperatures are equal. A current of air, moving swiftly across the outlet of a flue, has the same effect on the contents of the flue as that of a common hand atomizer has on the contents of the tube. The air in the upper part is carried along mechanically, a partial vacuum is formed, and that which is below rises to take its place, and is in turn carried away. In the case of the flue, air from below is constantly drawn up and dissipated; in the case of the atomizer, the liquid into which the tube dips

is lifted and blown into spray. This influence is utilized and assisted by various forms of cowls placed over outlet flues; some of these, however, although they seem to be an aid, are really a hindrance to the outflow, as may easily be demonstrated.

In Figs. 39 and 40, are shown forms of cowls which offer some assistance to the aspiratory influence of winds, and in Fig. 41 is shown another very popular kind, the rotary cowl, which offers an obstruction to the passage of air. As the wind causes the top to revolve, the impression is made that work is being performed; that in its revolutions it is creating a suction which causes an upward current of air. As a matter of fact, however, it is doing no such work, but is, on the contrary, interposing an obstacle to the passage of air. This may easily be demonstrated by measuring by means of an anemometer the amount

FIG. 42.



Aspirating cowl with vane.

of air discharged through the flue during a given period while the revolving top is in place, and again during an equal period while it is removed. The difference between the results obtained will invariably be in favor of the period during which the cowl is absent.

Other forms of cowls, constructed so that their outlets are turned by means of a vane away from the wind, are useful in assisting aspiration. Such a form is shown in Fig. 42. By reversing the position of the vane, the mouth of the cowl is turned toward the wind so that the flue is converted into an inlet for fresh air.

Natural Ventilation.

Ventilation that proceeds from the operation of natural forces is known as "natural ventilation." For the attainment of the largest results, these forces must be assisted to the extent of removal of obstacles to their action so far as may be advisable. It is not well to depend upon the chance cracks and upon the migration of air through the pores of building materials, but necessary openings, both inlets and outlets, should be provided. The greater the obstacles to the escape of heated air, the less the opportunity for successful natural ventilation.

The extreme of obstruction to the escape of contained air may be illustrated by an hermetically sealed metallic box or by a closed glass bottle. Suppose we provide one small opening in the side of the box or in the stopper of the bottle to act as an outlet and inlet, and observe the result. According as the contained air is warmed or cooled, the opening will act as an outlet or as an inlet, but only to a limited extent. The expansion due to heating will cause the escape of a portion of the contents; the contraction due to cooling will cause the indrawing of some of the outer air; but in either case, the movement is all one way, and there is no real interchange. Suppose, however, two openings are supplied; then one may act as an outlet, the other as an inlet, and a constant inward and outward current may be maintained.

The more tightly fitting we make our windows and doors, and the more impervious to air we make our walls by means of paint and sheathing paper, the more do we oppose natural ventilation. On the other hand, the intelligent placing of inlets and outlets furthers the object to be achieved.

In addition to permanently installed inlet and outlet flues, temporary openings may be utilized whenever desirable. The most available of these is the opened window, which may be utilized so as to avoid too voluminous exchange and unbearable draughts. The area of the opening may be very simply regulated, and the air may be deflected upward or the current may be broken up by the interposition of fine wire gauze, flannel, or other pervious material.

A very common plan is to place a board lengthwise under the lower sash, so as to fill completely the opening made by raising the window, and thus establish an inlet or outlet where the sashes overlap each other, for the barrier to the movement of air, formed by the juxtaposition of the lower border of the upper sash and the upper border of the lower one, no longer exists, and the entering current, moreover, is given an upward direction. Instead of a board, a frame, over which a diaphragm of flannel is fastened, may be used. This arrangement is pervious to air but impervious to dirt, which, therefore, is filtered out. Movable panes, either sliding or swinging by the side or end, are frequently employed, especially in double windows. There are also numerous patented devices for window ventilation, all designed with the idea of dividing or deflecting the current of admitted air.

As has been remarked above, the most important force in natural ventilation is that dependent upon unequal temperatures of bodies of air; in a perfect calm and with equal temperatures, natural ventilation would have to depend wholly on the force of diffusion.

The enormous influence exerted by the heating and lighting of a building or room on its ventilation becomes, then, self-evident, but it is not simply as a motive force that the relation between heat and ventilation is so close and important, for the incoming air must be raised to an agreeable temperature in order that the space may be habitable. Thus, a very large share of the cost of heating is chargeable to ventilation, whatever the system of ventilation be. In the matter of expense, the amount of leakage through cracks and other small openings is, in a certain class of cases, of very great importance. In our dwellings, it is important that the interchange of air shall proceed continuously in the inhabited parts, but in buildings which are used only by day, and perhaps for only a few hours daily (schools, etc.), it is not essential that the air shall be renewed constantly at other times; and here it is wise to obstruct the leakage as much as possible by perfect construction and by dampers in the flues, so that waste of heat, fuel, and money may be prevented.

For the promotion of the process of natural ventilation, a number of "systems" have been devised, many of which can be productive of no results other than incomes for their promoters. As a rule, most of those noticed in works of this character are either ill-adapted to the conditions of our climate or incompatible with our methods of building, and will, therefore, not be considered here.

The only system of natural ventilation worthy of advocacy is that which provides proper inlets and outlets and a suitable means of heating.

Inlets and Outlets.—As to the size, location, and number of inlets and outlets, no hard-and-fast rules can be applied for all cases, since the conditions are widely varying, and many different circumstances have to be taken into account. But general rules may be laid down.

If several inlets are to be provided in a room, it is essential that they should be distributed in such a manner as to insure a thorough blending of the admitted air. They should not be so placed, with reference to outlets, as to favor the forming of direct currents between them, whereby a large proportion of the inflowing air is discharged without having fulfilled its function—a not unusual condition, which illustrates that the amount of air admitted is not by any means a measure of thoroughness of ventilation. Their location is not such an important matter as the placing of the outlets, but, in general, an inlet is placed best on an inner wall where it shall be most nearly central in relation to the outside walls.

With reference to the floor, if the incoming air is heated, inlets may be placed high or low; but if it is admitted cold, they should be at a higher level than the heads of the occupants, and provided

with arrangements for deflecting the current toward the ceiling. This may be accomplished by causing the current to impinge upon a surface slanting upward. The results of this deflection are that the fresh air becomes mixed with the warmer air, and that more time is required for it to reach the lower parts of the room, when it will have become sufficiently warmed not to cause discomfort. The interposition of the deflecting surface also spreads the current radially and reduces its velocity. The incoming air becomes mingled with the general supply and joins the currents which are constantly in motion. That which comes in contact with cooling surfaces, such as windows and outside walls, is cooled, and, therefore, falls toward the floor, and that which takes its place as it falls is cooled in its turn and follows after, so that currents are established, which tend to keep the whole bulk in more or less rapid motion. As these currents reach the floor, their natural trend is across that surface toward the inner warmer walls, where they become heated and are inclined toward the ceiling, reaching which, they are pushed by the force behind and drawn by the one in front toward the outer walls and windows again. In the meantime, some of the air is escaping through outlets, and diffusion of the impurities is proceeding, so that a more or less even character is brought about throughout the air of the room.

Outlets may be placed at the level of the floor, in the ceiling, or at any height in the walls, according to the conditions of each individual case. If the incoming air is not heated, the outlets should be placed high up, for where only unheated air is admitted, the warmest air must be the oldest and its location will be in the upper air space. If, on the other hand, the air is heated, the outlets may be anywhere so far as height is concerned, but there is some choice in locations with respect to inner and outer walls. Outlets placed beneath windows or near outer walls will withdraw the falling currents of the only recently introduced air before it has had an opportunity to become well mixed by passage across the floor to the other side, and before it has in any proper degree fulfilled its functions; but if its passage through the lower strata is not interrupted in this manner, it is enabled to mix with and dilute the impurities of the air already vitiated, and thus effect a large measure of work, and so when it reaches the other (inner) side and finds an outlet for its escape, there is no objection to its withdrawal, and, indeed, its removal then is highly desirable. Hence, and for another reason as will appear, outlets should be placed in inner walls rather than near or in outer cooler ones, and near the floor where they may intercept the air before it may again become a part of the ceiling currents.

If but one outlet is to be provided, it should be placed with reference to the most even movement of the current over the whole area, having in mind the fact that the air movement toward it is convergent, and the direct reverse of the flow from the deflecting and diffusing surface at the inlet.

As to size, it may be said, in general, that a single outlet, or the

aggregate if there be more than one, should be of such size as to insure the possibility of removal of such an hourly air supply as the space is likely to require under the ordinary conditions of its usual occupancy; that it should not materially exceed this limit; and that the final velocity of the outflowing current should not be productive of the sensation of disagreeable draughtiness.

As to the shape of inlets and outlets, it is self-evident that, with equal areas, that which has the smallest periphery will offer the least frictional resistance, and is, therefore, best adapted. Thus, a circle enclosing an area equal to a square foot has a smaller periphery than a square enclosing the same area, and a square has a smaller one than an oblong rectangle. Take, for instance, a square foot; it may be included within boundaries:

12 × 12	inches, a square.	
16 × 9	"	oblong rectangles.
18 × 8	"	
24 × 6	"	
36 × 4	"	
48 × 3	"	
72 × 2	"	
144 × 1	"	

With these boundaries, the periphery ranges from 4 feet (the smallest) to 24 feet 2 inches. The frictional resistance will, therefore, be greater in proportion as the shape varies from the circle and square.

The shafts communicating with the inlets and outlets should be so disposed in the general plan as to offer the least resistance to the inflow and outflow of air. Unless they are heated artificially, inlet flues should not be located in outer walls, on account of the likelihood of the formation of down draughts due to cooling of the air column. Their inner surface should be as smooth as possible, in order to bring to a minimum the loss of movement due to friction, and they should be cylindrical, if possible, for the same reason. They should be as free as possible from angles, and especially right angles, because of the very serious loss of motion which these cause, each right angle diminishing the current about half; thus, after passing one right angle, the flow would be half; after a second angle, the half would be reduced to a quarter, and after a third, to an eighth. The neglect to take into account the loss of flow by friction, bends, and angles is responsible for the failure of many a plan for ventilation.

What has been said concerning the impossibility of making general rules for the sizes of inlets and outlets applies with equal force to the fixing of sizes of flues, for these depend upon the many and varied conditions which, even under the best favoring circumstances, affect the rate of flow.

In planning inlet and outlet shafts, it is to be borne in mind that something more is necessary for their proper working than the dictum that this one is for fresh air and that one for foul, for natural forces have no respect for mere names and plans, and the current in a flue will be upward or downward, inward or outward according to natural

laws. Outlet shafts may become considerably cooled by low external temperatures; they may be invaded by rain and snow, the evaporation of which causes cooling and, therefore, increase in gravity; or there may be an insufficiency of inlet air, so that a partial vacuum is formed by the current of one large outlet flue, which thereby causes a reversal of that of a smaller one, so that one flue draws against another. It is from any one of these causes that a chimney may fail to discharge smoke upward—a circumstance noticed more often in summer than in winter.

Mechanical Ventilation.

Mechanical ventilation consists in the propulsion or extraction of air by means of blowers or exhaust fans driven by steam or electricity. That in which the air is propelled by the action of a blower is known as the "plenum" system, and the other, in which it is withdrawn by an exhaust fan, is known as the "vacuum" system.

In the plenum system, the air is drawn into a box, in which the revolving blades of a fan are located, and it is then driven into a central conduit, and from there through appropriate shafts to the spaces for which it is intended. When it is desired, the air may be received from or blown first into a chamber where it may be heated. The air supply may be regulated very easily by diminishing or increasing the number of revolutions per minute, but it should always be in slight excess of the real need, in order to produce a slight outward pressure, which will prevent inward leakage.

In the vacuum system, the air is extracted from the various rooms through pipes leading to a central shaft, where it is drawn into the fan and discharged outwardly. This system has among other disadvantages that of great inequalities in draught in the different discharge tubes, and that the vacuum condition favors the inward leakage of cold air through cracks, walls, and about windows, and tends to cause cold floors and disagreeable small draughts about windows. In consequence, more fuel is needed for the maintenance of a proper temperature, and the system is, therefore, a source of greater expense.

The advantages of mechanical ventilation lie in the fact that the object sought is attainable in any and all conditions and variations of weather, and that less space is required for shafts than in the case of natural methods.

Mechanical ventilation on a comparatively small scale is employed commonly in crowded offices and other spaces by means of small extracting fans run by the aid of electricity (connection being made with the electric light system) in specially provided locations connected with outlet flues, or directly in a space made by removing window panes.

Artificial Heating in Its Relations to Ventilation.

First, for the proper understanding of the subject of heating in its bearings on ventilation, it is necessary to consider the different ways

in which heat is imparted. These are three in number: radiation, conduction, and convection.

Radiation.—Radiant heat passes from its source through the air to bodies by which it may be absorbed, transmitted, or reflected. Air, being "transparent" to heat, is not materially affected, and the drier the air, the less heat it will retain. It passes directly from its source in waves, like the waves of light, to the object upon which it falls, and the amount reflected or absorbed varies with the nature of the object, its color, the character of its surface, and its temperature. Its intensity varies inversely as the square of the distance between the source and the object upon which it falls; thus, the amount received by two objects 1 and 5 feet respectively distant, will be inversely as 1 and 25; at 1 and 10 feet, inversely as 1 and 100; at 5 and 10 feet, inversely as 25 and 100; that is, the nearer will receive in the first instance 25 times; in the second, 100 times; and in the third, 4 times as much as the farther object.

As an instance of radiant heat, we may take that which proceeds from an open fire. The heat passes in direct lines through the air to the walls, floor, ceiling, furniture, and other objects in its path, and these absorb some and reflect the rest to other parts of the room. It directly warms only that surface of an object that is directly opposed to it. The objects by which it is opposed then disseminate it in two ways: by conduction and convection.

Conduction.—Conducted heat is that which passes from one particle of matter to another in direct contact; that is, from one particle to another of the same object, or from one object to another which it touches. Conduction acts through all solid substances, but by no means to the same extent, some being good, some indifferent, and others bad conductors. The best conductors are metals, and these vary within very wide limits; copper, for instance, is a very much better conductor than iron or zinc. Wood is a poor conductor, and woven and felted materials and asbestos are very poor. Through liquids and gases, heat is conducted to only a very limited extent, but there is no substance known that is absolutely non-conducting.

Good conductors permit a rapid flow of heat through their substance; poor ones, only a slow transmission. Good conductors relinquish their heat rapidly to their colder surroundings, whether air or anything else, and withdraw heat from bodies which are warmer than themselves.

Convection.—Convection is the process by which heat is communicated to gases and liquids, acting through their mobility, which permits those parts that have been expanded by reason of becoming heated to be displaced upward by cooler portions, which, in their turn, receiving heat, give way to others, until the whole mass becomes raised in temperature by continued application of heat and consequent maintenance of circulation.

Every warm body with which air comes in contact communicates its heat to those portions in its immediate vicinity; these expand and are forced onward by the cooler heavier parts nearest them; these in their

turn give way to others, and convection currents are established to such an extent that the air of a room takes on a very complicated state of activity.

Convection currents are established by every person in a room so long as the temperature is below that of the body. They are established by the warmer walls, floor, furniture, hot-water pipes, steam radiators, close stoves, and other warm objects, and in this way the air becomes heated. The air which enters rooms through shafts communicating with the air chambers of furnaces and "indirect radiation" apparatuses are convection currents in the largest sense. The direct rays of the sun, passing through windows and absorbed by the floor, walls, and other objects which they strike, also cause upward convection currents.

Methods of Warming.—The principal methods of heating houses and rooms are: 1. Open fires. 2. Stoves. 3. Furnaces. 4. Hot-water pipes. 5. Steam pipes. The method most applicable in any particular case will depend upon the size of the room and the number of rooms in the building. In general, it may be stated that the smaller the space, the more simple the method. For a single room, an open fire or a stove will be sufficient; for a small house, stoves or a furnace; for a large one, one or more furnaces or hot-water or steam apparatus; and for large buildings—office buildings, for instance—"direct" or "indirect" steam.

1. **Open Fires.**—Practically the whole of the heat supplied by an open fire is radiant. If the fuel is held in a grate, there is, of course, a certain amount of conduction from the bars, and of convection currents in the air in its immediate vicinity. But this heat does not get out into the room, because it is immediately carried up the flue by the draught of the chimney. The radiant heat is absorbed, reflected, and distributed in the manner already described, but reaches directly only those surfaces which are opposed to its source—which accounts for the saying that, in a cold room with an open fire, "one side roasts while the other freezes." Only a small part of the total heat of the fuel consumed is available for heating, since most of it—about seven-eighths—is carried at once up the chimney. An open-fire stove, such as the old-fashioned "Franklin," which stands out in the room, and is connected with the flue by stove piping, yields a large amount of its heat, since the material of its construction is heated by conduction and then gives it off to the air by convection.

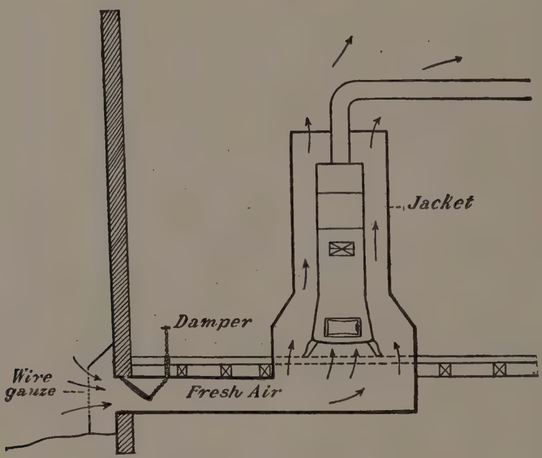
Open fires cause the introduction and removal of large volumes of air, but these are by no means always well mixed with the whole mass of contained air. Nevertheless, a large measure of ventilation is accomplished, a certain amount of heat, perhaps sufficient for immediate needs, is given off, and there is also an unmeasurable addition to the general cheerfulness. They may cause too much draught, and they are certainly not economical, but as accessories to other heating methods they may be most useful.

2. **Stoves.**—Close stoves have more direct results in heating and less

in ventilating than the open fire, for more of the heat produced is available, and they discharge into the chimney only the air volumes that have passed through them. The materials used in their construction, iron, soapstone, brick and fireclay, conduct the heat and give it off to the air with varying rapidity; cast iron yields it about as rapidly as it is received, soapstone and brick give it off only gradually, but for a longer period.

When cast-iron becomes red hot, it may be decidedly objectionable for two reasons: first, that the organic dust particles in its immediate vicinity become charred and yield odors; and second, that it absorbs and transmits considerable carbon monoxide from burning coal. Stoves may be so arranged as to act not alone as heaters, but as ventilating apparatuses, and this fact is of very great value in the case of small school buildings in country districts. The stove, standing out in the

Fig. 43.



Jacketed ventilating stove.

room, may be surrounded by a cylindrical jacket from the floor upward, leaving a sufficient air space between the two. Through the floor within the enclosure, is an opening into an air duct communicating with the outdoor air. The heat of the stove is communicated to the air between the latter and the jacket and an upward current is formed, which draws upon the fresh-air conduit, so that a constant current of warmed pure air is thrown into the room. (See Fig. 43.) It goes without saying, that here, as elsewhere, the incoming air must be taken from points where its purity cannot be interfered with by local conditions.

Gas stoves and oil stoves have the advantage over others that they are more prompt in results, more easily controlled, and more quickly put out of use. They have the disadvantage, however, that the products of their fuel combustion are discharged directly into the air of the room. In the case of the oil stove, this is not such a serious matter,

since the perfect combustion of good oil results in carbon dioxide and water; but with gas the products are more numerous and varied, and include some that are irritating and poisonous. With proper ventilation, however, in the case of both, no harm will be done.

3. **Furnaces.**—Hot-air furnaces are not only of very great importance as heaters, but of enormous influence in ventilation. In their use, the cold outdoor air is brought in by a conduit, the "cold-air box," to a chamber in the upper part of the furnace, above and surrounding the "dome," where it comes in contact with the very hot surface and is heated by convection. Thence it passes upward through separate tin tubes to the several places for its discharge. In a house which is unprovided with special inlet and outlet flues for ventilation—and most of our houses are so constructed—a furnace of ordinary heating capacity performs an amount of ventilating work quite sufficient for all needs, and for which it rarely receives credit. It discharges into the various rooms a constant supply of warmed fresh air. Where and how it all escapes is a matter of secondary interest and importance, for it gets out wherever it may find its way.

4. **Hot-water Pipes.**—Hot-water heating depends upon the circulation of water by convection currents through a system of pipes which may extend all through a large-sized building. The water is heated in a boiler below and passes through a main, leading from the upper part thereof. As one portion of water comes in contact with the heating surface and expands, it is moved along, and the circulation becomes established just as with air. The "main" gives off branches where needed, and these at their extremities turn back and become "returns," which eventually connect with each other and form the "main return," which, conveying the cooled water, enters the boiler at its lowest point. The first part of this system may be compared with the arteries, and the "returns," with the veins of the body. Vents are provided for the escape of dissolved air liberated from the water, and "cut-offs" are inserted for the shutting out of any part of the system as desired. It is very necessary that air should not be allowed to accumulate in the pipes, since it will stop the flow. In low-pressure systems, a small cistern is provided to allow for the expansion of the water and to prevent its overflow. The hot-water system may be of either high or low pressure. With high pressure, the pipes are smaller and necessarily stronger, and the water is heated to a considerably higher temperature (300° F.), and hence circulates more rapidly. With the low-pressure system, the water does not go much, if any, above 212° F.

With the hot-water system of heating, the air is heated mainly by convection, though from polished pipes a certain amount of radiation occurs. With high pressure, the air may easily be overheated.

5. **Steam Pipes.**—In steam heating, the system is very like that of hot-water heating, except that steam is the circulating medium instead of water. With steam, and, indeed, with hot water, heat may be distributed by the "direct" or "indirect" methods. In the "direct" method, the pipes are distributed within the space to be heated, and the

air of each room is heated separately. In the "indirect" method, the heating surfaces are all concentrated in the basement, and are enclosed in galvanized iron conduits, which receive and conduct the air just as in the case of the hot-air furnace. The two methods, it will be noticed, vary widely in the matter of assisting ventilation; the direct brings in no air, but heats that which is at hand; the indirect brings in large volumes of heated fresh air, and thus insures change of air.

In conclusion, may be mentioned the considerable heating and circulating influence of burning illuminating gas. By means of suitable outlets above the burners, gas may be made not only to discharge the products of its own combustion, but to send out large volumes of otherwise vitiated air as well. Nor is the heat of the sun so insignificant that it may be passed by without notice in the planning of systems of ventilation. Inasmuch as the difference in temperature of the outside air on the north and south sides of a house averages about 5, and may reach 10, degrees F., just that amount of advantage may be gained by taking the air for ventilation from the warmer side. In gravity ventilation, the inlets should be where they may face the prevailing winds.

Regulation of Temperature.

In carrying out any scheme of efficient ventilation, it is necessary to guard against overheating, which may not be noticed until it becomes so marked that it cannot help attracting attention. When such is the case, the common practice is to cause a lowering of the temperature to the desired point as soon as possible by opening windows to admit the colder air. The consequence is the production of a distinctly cold atmosphere, more so than ordinarily is shown by the thermometer, which does not react very promptly to sudden changes. This produces chilly sensations which call for a return to the original condition. In the meantime, a lot of heat has been wasted and the foundation for a cold has, perhaps, been laid. If windows are left open in the upper stories, as often happens in overheated buildings, there are constant outflow and waste of heated air, with a corresponding inflow of unwarmed air below, which requires the expenditure of additional fuel in order that the lower stories shall be properly warmed. In overheated buildings, there is also the additional loss from outward leakage through all possible outlet channels.

To prevent waste of heat in properly heated buildings, we have recourse to double glazing and double windows. Double glazing is accomplished by fitting two panes into each space, instead of one, with a space of a quarter or a half inch between them. By this means, the loss of heat occurring through ordinary windows is reduced about one-third, which means a saving of considerable fuel, since the loss of heat by conduction through glass windows is very considerable. Double windows are still more efficient as heat-savers. Here the outer window is made to fit as accurately and closely as possible by

the use of listing, and we have between the two windows a fairly deep space filled with air, which is a very poor conductor of heat. It is on the same principle that we use loosely woven woollen goods and furs, which hold within their meshes and between the hairs a large amount of this poor conductor. The loss of heat through walls is lessened when a similar air space exists within them; a solid wall will conduct a very large amount of heat and waste it, while the same amount of building material, or considerably less, may be so disposed as to bring this loss down to a minimum.

Loss of heat is caused also by dampness of walls, for a continual evaporation goes on from their surface, and this requires heat and produces cooling. Every ounce of moisture so vaporized requires the consumption of extra fuel.

Necessity of Providing Moisture.

Concerning the need of insuring a normal amount of moisture in the air of heated buildings, there is more or less difference of opinion, but the weight of evidence from a medical standpoint and from our own sensations points to the advisability of introducing an amount of moisture sufficient to bring the relative humidity of the air to 50 or 55 per cent.

The lower the temperature of a body of air, the less the amount of moisture it can hold, and what would be saturation at a low temperature would be but a very low relative humidity at a high one. For instance, a volume of air at 0° F., containing its fullest possible amount of aqueous vapor, admitted to the cold-air box of a furnace and then heated to 85° F. before being conducted to the rooms of a house, will have at its new temperature but a very small relative humidity. It will be so much drier than any outside air, that that of the driest climate in the world will be moist in comparison. The great majority of U. S. Signal Service Stations have a mean relative humidity of 65 to 75 per cent.; only twenty-four show below 60 or over 80, and the very lowest is in the hottest part of Arizona, where newspapers crack when handled, glued furniture falls apart, and the skin becomes hard and dry. At this place, Fort Yuma, the mean relative humidity is 35 per cent.

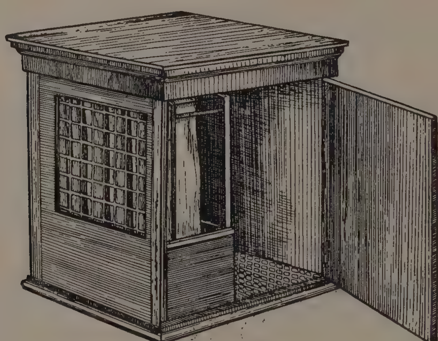
When outdoor air is heated so as to maintain an even temperature of 70° F., but with no addition of watery vapor, its capacity for absorbing moisture is very much increased, and it will take it up from all moist objects with which it comes in contact. It will take it from the skin, from the mucous membranes of the mouth, nose, and respiratory tract; from furniture made from wood which, in the process of kiln-drying, was never brought to such dryness; from the leather bindings of books, causing them to crack and fall to pieces; and from plants, which, in consequence, wither and die. It thus causes more or less dryness of the skin, irritation of the throat, and cough. It causes also need of a higher temperature to give the same sensation of warmth

and comfort than is the case with air containing a normal amount of moisture. It is on account of the disagreeable and destructive effects of extreme dryness that water-holders are attached to furnaces and stoves so as to give moisture to the heated air. But even when attention is paid to keeping them full, which is not often, they are very inadequate for the purpose.

Air at 25° F., saturated with moisture and then heated to 70° F., would need more than 0.5 pint of water in every 1,000 cubic feet to give it a humidity of 65 per cent., and this is far in excess of the capacity of the ordinary waterpot of the furnace, as is seen when we reckon what 0.5 pint per 1,000 cubic feet means in the course of a day.

Moisture may be imparted to the air by exposing pans or porous vessels of water to the heated current, or by means of the "humidifier," which exposes to the air passing through the registers a surface of cotton wicking communicating with the reservoir of water. (See Fig. 44.) With this device, Dr. H. J. Barnes, of Boston, reports

Fig. 44.



Humidifier.

that he is able to keep his office at 53 per cent. relative humidity by evaporating an average of 4.5 quarts of water per day. At the same time, he finds a temperature of 65° to be perfectly comfortable where before he had required 70° or 71°.

On a larger scale, water may be vaporized into the air in the form of steam from a boiler. In the building of the American Bell Telephone Co., in Boston, a building having a capacity of 450,000 cubic feet and a day-time population of more than 450 persons, the air, which is distributed by the mechanical system, is drawn into the building at the rate of 26,000 cubic feet per minute, heated to about 100° F. in the stack room, and moistened so as to contain about 50 per cent. relative humidity. For the production of this condition, no less than 675 gallons of water in the form of steam are given to the air in ten hours, or about one and a half barrels per hour. Certain parts of the building which, before the adoption of this process, had

been heated with some difficulty, are now made more comfortable, and in the whole building 3 degrees less heat are required for the maintenance of an agreeable temperature. According to Mr. C. J. H. Woodbury,[1] under whose direction the plant was installed, "another feature indicating the greater comfort of the building was the absence in winter of the coughing by those employed there, a cough of the bronchial kind or from the larynx, a cough which ends with a squeal, which is so prevalent in New England during the winter, especially in those employed in offices."

Filtration of Air.—Here may be given an instance of the benefit derived from filtering large volumes of air introduced into a building for purposes of ventilation. In the building above mentioned, the air is drawn into and through a system of large cotton bags 30 feet in length, in which all dirt and dust is retained. About a peck per month is separated in this way from the air, which is drawn not from the street level, but far above it. An analysis, chemical and microscopical, made in April, 1897, showed 22.67 per cent. of organic and 77.33 of inorganic matter. The material consisted of all manner of animal, mineral, and vegetable substances ordinarily present in the dust of large cities.

Determination of Rates of Ventilation.

The estimation of the amount of air entering and leaving a room through inlet and outlet flues is a very simple matter, but the results may not be accepted as an indication of the efficiency of ventilation, since it so often happens that much of the effluent air has failed to perform its full duty in diluting the impurities arising from respiration and combustion. Nevertheless, such a determination may yield important indications.

In order to ascertain the volume of air passing through an opening, whether inlet or outlet, it is necessary to know the area of the opening and the velocity of the current. The former is easily calculated arithmetically; the latter can be found only by the use of an anemometer, an instrument of very delicate construction, which registers the distance travelled by a current of air in any period during which it is exposed.

A current of air, passing through an opening, has not the same velocity at all points of its cross-section. It moves in the same manner as a river—faster at its center, where it is least subject to the influence of friction. Therefore, the velocity should be taken at different points, and the mean of the results accepted as its true rate of movement. The anemometer is held for a given time, say half a minute, at a point at the periphery of the opening, and then moved along a short distance and held for an equal period, and so on, from point to point, until the whole area has fairly been traversed. The reading of the instrument is then noted, and the distance indicated is divided by the number of

[1] Transactions of the New England Cotton Manufacturers' Association, Vol. 63.

points where stops have been made. The quotient equals the distance travelled by the whole current during the unit of time employed. It will be found most commonly that the movement at the periphery is very slow, and that, as the center is approached, the velocity becomes greater and greater, the maximum being attained at the center. Knowing the average movement in feet or meters, the volume is calculated by multiplying this by the area in square feet or square meters, the product being the volume in cubic feet or cubic meters passing during the unit of time. From this result, the volume per hour is easily made known.

Example.—The size of the opening is 2 by 3 feet; the area is, therefore, 6 square feet. The anemometer, held at twenty-four points for fifteen seconds each, registers 228 feet. The mean of this is 9.5 feet, and the current is moving, therefore, at the rate of 38 feet per minute. The cross-section of the current being 6 square feet, the volume discharged in a minute equals 6 × 38, or 228 cubic feet, and, in an hour, 13,680 cubic feet.

By determining the rate of discharge through all inlets and outlets in this manner, an idea is obtained of the amount of ventilation occurring through means provided, but, as has been stated, not of its efficiency. The sum of the inlet discharge will almost never agree with that of the outlet, since much air enters and leaves a room through other openings. Knowing the capacity of the room, we learn from the amount of inlet air the number of times the air of the room has been replaced.

The full measure of ventilation and its efficiency may be determined very closely by methods originated by Pettenkofer. One of these consists in first creating an unusual degree of impurity either through respiration of a large number of persons, as, for instance, by children occupying a schoolroom, or by burning a number of candles, or by other chemical processes, then, after taking a specimen of the air for analysis, keeping the room closed for an hour or two. At the expiration of the allotted time, a second sample is taken, and from the results of the two analyses, the rate of ventilation is ascertained by means of Seidel's formula, which is as follows:

$$C = 2.303 \text{ m. } \log \frac{p_1 - a}{p_2 - a}.$$

in which C = amount of air which has entered.
2.303 is a constant.
m = capacity of the room.
p_1 = amount of CO_2 originally present.
p_2 = amount of CO_2 at the end of the experiment.
a = amount of CO_2 in the external air.

Example.—The air of a schoolroom of 500 cubic meters capacity, accommodating 34 children, contains at the end of the session 18.5 cc. of CO_2 in 10,000, or 0.00185 : 1. At the end of an hour, a second analysis shows 8.5 cc. of CO_2 in 10,000, or 0.00085 : 1. The outer air contains 3.5 cc. of CO_2 in 10,000, or 0.00035 : 1.

Then

$$
\begin{aligned}
C &= 2.303 \times 500 \times \log \frac{0.00185 - 0.00035}{0.00085 - 0.00035} \\
&= 1151.5 \times \log \frac{0.0015}{0.0005} \\
&= 1151.5 \times \log 3 \\
&= 1151.5 \times 0.4771213 \\
&= 549.4 \text{ cubic meters of air in an hour.}
\end{aligned}
$$

Thus, the air of the room is renewed but once and a tenth per hour, and the result shows that the per capita ventilation is about a fifth of what it should be.

The other method consists in imparting to the air of a room a continuous supply of carbon dioxide by means of burning candles, and making periodical analyses of the contained air. Candles of pure stearin, 1 gram of which yields 1.404 liters of the gas, are employed. A preliminary analysis of the air is made, and then a number of the candles, the combined weight of which is noted, are placed about the room and lighted. At stated intervals, the room is entered, and after the air has been well mixed by vigorous fanning, samples are taken for analysis. At the end of the experiment, the candles are put out and reweighed, and from their loss in weight and the results of the analyses, the amount of ventilation is calculated by means of a most complicated formula devised by Hagenbach.

Other methods have been proposed by Recknagel, Petri, and others, but they present no advantages, and are, in general, so complicated that in the hands of other than expert physicists they are quite useless.

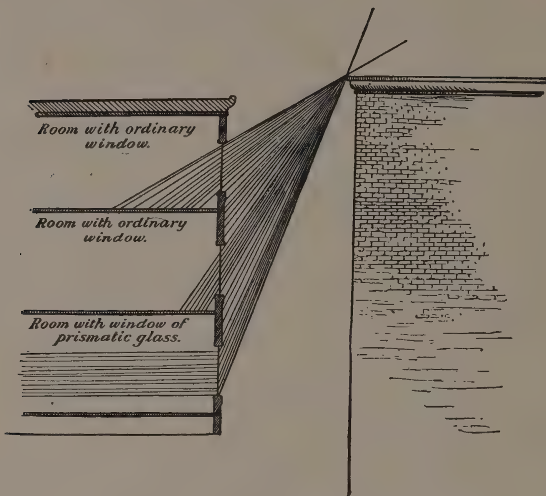
Section 3. LIGHTING.

Natural Lighting.—In natural lighting, the light enters the room directly or by reflection through the windows, and is then reflected to different parts of the interior, which receive different amounts of light according to circumstances. Thus, white and light-colored walls, floors, and articles of furniture reflect and disperse the light, while dark walls, draperies, and other objects absorb it. Large rooms having but small window area and all rooms, however generously provided therewith, looking on narrow alleys or streets in which the opposite buildings are so high that the sky-angle is small, cannot be illuminated uniformly by diffused daylight without some assistance.

The means employed are exceedingly simple, and the discovery of their utility for this purpose was due to chance. In order to obstruct the view into factory workrooms from the outside, and to lessen the temptation to operatives to waste time in looking out, ribbed glass was introduced instead of ordinary glass for use in windows, and it was noticed that not only was the desired end attained, but that the light from the windows was projected farther into the rooms, and to such an extent in some instances, that artificial lights, required before in the brightest part of the day, could be dispensed with. Attention being thus drawn to the great advantage and saving of expense, a num-

ber of different kinds of glass with uneven surface have been placed upon the market and have come into very extensive use. The best of these, which is the most expensive, is known as "prismatic glass" from the fact that one surface consists of a series of prisms running horizontally. The entering light, instead of falling directly to the floor, is

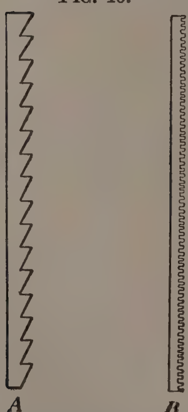
FIG. 45.



Action of prismatic glass in projecting light.

tipped up and projected toward the opposite sides of the room, as shown in Fig. 45. Vertical section of a sheet of the glass is shown at *A* in Fig. 46. By varying the angle of the prisms, the conditions obtaining in any situation can be met and light may be projected in any desired direction. Naturally, the prisms cannot be used indiscriminately, for a series adapted to light the entire lower part of the room with a certain sky angle might, when applied to another, throw the light toward the ceiling instead of to the parts where it is required. Therefore, to meet all conditions, the glass is made with a great range of angles, and the particular kind needed in any situation is determined by measurement. Where the sky angle is very small, canopies, hung at the proper angle above the windows, serve to throw inward a flood of light. The disadvantage of prismatic glass is its great cost.

FIG. 46.



Vertical section of prismatic and ribbed glass.

Ribbed glass is very efficient and much less expensive. This is made with 4, 5, 7, 11, and 12 ribs to the inch, and of different thickness and weight, since the fewer the ribs, the deeper they must be cut, and the thicker, therefore, the

glass. Vertical section of a sheet of ribbed glass is shown at *B* in Fig. 46.

Artificial Lighting.—The methods of artificial illumination comprise electric lighting and those dependent upon the combustion of oils, gases, and hard fats. The oils employed are chiefly of mineral origin, but animal and vegetable oils are used to some extent, although not very much in this country. Hard fats in the form of candles are used very extensively in all countries, on account of safety, cheapness, and general availability. The gases in common use are derived from coal and hydrocarbons. Of late, acetylene gas, obtained by the action of moisture on calcium carbide, has come into extensive use.

Luminosity of Flame.—In the combustion of a candle, it will be observed that the flame consists of four parts, the lowest of which, blue in color, gives out practically no light; the middle portion, dark in color, consists of hydrocarbon gas generated from the substance of the candle; next is the luminous yellow portion; and outside of this, is an almost invisible envelope. The atmospheric oxygen, moving toward the inner portion of the flame, unites with the carbon escaping outward from the luminous portion, and forms carbon dioxide; more oxygen passes onward and inward, meets the hot gas from the central part of the flame, and, being insufficient in amount to unite with both the hydrogen and carbon constituents, combines by reason of greater affinity with the hydrogen, leaving the carbon free, but so much raised in temperature that it becomes incandescent, thus furnishing light during the extremely slight interval elapsing in its passage to the outermost portion of the flame, where, as has been stated, it is oxidized to carbon dioxide. The same process goes on in the combustion of illuminating gas and oils, the luminosity of the flame being due to the incandescent particles of carbon in the breaking up of the hydrocarbon compounds into their elements. A mixture of gas and air, such as occurs in the use of the Bunsen burner, gives off little or no light, since each particle of carbon is provided with sufficient oxygen to convert it at once into carbon dioxide, and so incandescence cannot occur. If the air supply to the interior of the flame is shut off, luminosity is produced at once.

If the area of the outer surface of an ordinary gas flame is so small that atmospheric oxygen cannot be taken up sufficiently fast to unite with all the carbon arriving at the outer part of the flame, the unoxidized carbon becomes cooled below the ignition point and is given off in the form of smoke. Defects in the burner or excessive richness in hydrocarbons may cause smoking during combustion, the supply of air being too small to consume the carbon. The introduction of a cool surface into the luminous portion of the flame causes deposition of soot thereon. If the area of the flame is made too large by turning on a large volume of gas under high pressure, the gas is projected so far that it comes in contact with sufficient atmospheric oxygen to burn a large part of its carbon and hydrogen simultaneously, and, as a result, the excess of gas is consumed without luminosity and wasted.

Gas Burners.—The best of the burners in most common use is known as the *bat's-wing*, from the shape of the flame. The tip is hemispherical, and is provided with a single straight slit, through which the gas emerges in a thin flat sheet. Another, known as the *fish-tail*, contains in its tip two small orifices, through which the gas issues and then spreads out into a flat flame, shaped as the name indicates. This burner is inferior to the bat's-wing in that its flame is less luminous with the same amount of gas, and the orifices are much more easily fouled and occluded.

The *Argand* burner consists of a hollow ring, provided with a circle of small holes and attached by hollow arms, through which the gas is supplied, to a socket screwed to the pipe. The gas, issuing from the holes, forms a circular flame, which is provided with an abundant air supply which passes upward through the perforations of the holder for the chimney, which is an essential part of the apparatus, and through the central hole of the burner as well. The chimney should be of proper diameter and height to insure an air supply adequate for complete combustion of the gas.

The *Welsbach* burner, which may be taken as a good representative of the class of incandescent lamps, consists of a modified Bunsen burner, over which is suspended a mantle composed of incombustible material, which becomes intensely luminous when heated in the Bunsen flame, and thus transforms non-luminous heat energy into luminous light radiation. The mantles are made in different ways, of different materials, and are exceedingly fragile. One of the most common and best sorts is made by saturating a delicate network of cotton in a strong solution of several earthy oxides (cerium, zirconium, lanthanum, thorium), then baking, and finally heating it until the cotton fibers are destroyed, thus leaving a gauze composed of the oxides alone. No single earth is efficient by itself. The flame and mantle are protected by a cylindrical glass chimney, which serves also to steady the flame, and the whole is enclosed commonly in some form of globe or shade to modify the intensity of the light. By providing a suitable burner to insure the requisite degree of heat, any kind of combustible gas or oil vapor may be used. Lamps are made on the same principle for kerosene burning. The incandescent mantle not only gives out much more light than an ordinary or Argand flame, but does so at a much smaller expenditure of gas.

Objection is often made that the Welsbach light is very trying to the eyes. This is true; but the same objection may be urged against the sun and other intensely bright objects when looked at directly. The lights should be so placed that they will illuminate those parts where light is needed; and if they are likely to try the eyes, they should be enclosed in globes designed to soften the glare and diffuse the rays uniformly.

Varieties of Illuminating Gas.

Coal-gas is made by heating bituminous coal in fire-clay retorts, in which process the compounds of hydrogen and carbon are transformed into gaseous and other products. The gas is conducted by pipes to condensers and purifiers, where it is freed from ammonia, hydrogen sulphide, tarry matters, and other impurities, and then is carried to storage tanks. The purified product consists of about 50 parts of hydrogen, 35 of marsh-gas, 6 or 7 of carbon monoxide, and the remainder of ethylene and other hydrocarbons, and nitrogen.

Water-gas is made from coke or anthracite coal, steam, and petroleum. The coke or coal is placed in an air-tight cylinder lined with fire clay, and then is ignited and blown up to a white heat by means of a blast of air. The air is then shut off and a current of steam is blown through. This is decomposed by the great heat into hydrogen and oxygen, the former passing on uncombined, and the latter uniting with carbon to form carbon monoxide. The resulting mixture is then carried to a gas-holder, from which it is conducted to the "carburetter," where it is enriched, in order that, when burned, it shall produce a luminous flame. This is a chamber of fire-brick kept at red heat. Here, vaporized petroleum is injected with the hot gas until the requisite percentage of carbon in the mixture is attained. The final product has much the same odor as coal-gas, but is of very different composition, and much more poisonous in character, containing about 30 per cent. of carbon monoxide, 35 of hydrogen, 20 of marsh-gas, and the remainder of ethylene and nitrogen. Water-gas may also be made by pumping crude petroleum in a small stream into a red-hot gas retort, where it is converted at once into vapor, which, with a current of superheated steam, is then driven through a long coil of pipe heated to a high temperature. The chemical reaction is the same, the carbon uniting with the oxygen of the steam to form carbon monoxide, leaving the hydrogen free.

The poisonous properties of both coal-gas and water-gas are due solely to the contained carbon monoxide, which, as shown originally by Claude Bernard, makes a definite compound with the oxygen carrier of the blood, the hæmoglobin, which then becomes incapable of performing its function. This being the case, the vastly greater danger attending the use of water-gas is self-evident. The odor of the two gases is practically the same in kind, but not in degree, so, in order to have the same value as a warning of danger from leaks, that of water-gas should be much more pronounced, since so much less of the gas is required to bring the air into a poisonous condition.

Usually about 0.4 per cent. of carbon monoxide in the air is required to produce fatal results, but less may be fatal after long exposure. In recovery from poisoning, the carbon monoxide is not oxidized in the body, but is driven out of its combination by the oxygen of the inspired air; but although after a few hours the blood may nearly be freed from the poison, the damage already done to the brain and other tissues

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through the temporary partial deprivation of oxygen may be severe and lasting. Recovery is accompanied commonly by severe headache, persisting for a long time, often with nausea and vomiting.

The increased danger of gas-poisoning when coal-gas is supplanted by water-gas with its high carbon monoxide content is well shown by the statistics bearing on the subject at Boston, Massachusetts. In 1888, when but 1 per cent. of the gas sold was water-gas, there were no deaths, suicidal or accidental, from gas-poisoning. In the following year, there was but 1. In 1890, the percentage of water-gas rose to 8, and there were 6 deaths, 4 accidental and 2 suicidal. In 1892, as a result of permissive legislation, 52 per cent. of the gas sold was water-gas, and the deaths rose to 15. In 1897, the percentage rose to 93, and the deaths to 47, 32 of which were accidental and 15 suicidal. In the five years ended September 1, 1899, 169 deaths had occurred.

On account of the danger, a commission appointed in England in 1899, reported adversely on all illuminating gas containing more than 20 per cent. of carbon monoxide, which proportion corresponds approximately to a mixture of equal volumes of coal-gas and water-gas.

Acetylene gas, C_2H_2, is an unstable compound of carbon and hydrogen. It has a strong, disagreeable odor. Mixed with air in the proportion of 1 to 19, it is violently explosive. It is poisonous, but not to the same extent as ordinary coal-gas; an animal exposed to an atmosphere containing it becomes unconscious after a time, with no manifestations of nervous or respiratory excitement, and, if removed at once, recovers in a very short time. Prolonged exposure is fatal. Blood will absorb about 0.8 per cent. of its volume of acetylene, but the solution gives no characteristic spectroscopic appearance. If any compound is formed with hæmoglobin, it must be very unstable. If a high percentage of oxygen be present, animals may survive its action many hours.

Acetylene is made from calcium carbide, a reddish-brown or gray material prepared by subjecting a mixture of lime and coke to very intense heat. When this substance is wet with water, a double decomposition occurs, the calcium uniting with the oxygen of the water to form quicklime, and the carbon with the hydrogen to form acetylene. Between four and five cubic feet of the gas are yielded by a pound of the ordinary commercial carbide.

Burned in ordinary gas-burners, the flame cannot secure a sufficient supply of oxygen for the complete combustion of the carbon, and in consequence it smokes and fails to exert its full power of illumination. By using a tip with an exceedingly thin slit, and forcing the gas through under heavy pressure, the flame is greatly enlarged and is of great brilliancy. Its illuminating power is about 15 times greater than that of ordinary gas.

Acetylene is liquefied at a temperature of 64° F. by a pressure of 1,200 pounds to the square inch, and may be stored in cylinders of steel. Apparatus for its use should not be made of copper or silver,

since these metals are attacked by it, and the resulting compounds are very explosive.

In some apparatuses in use, the water is dropped on to the carbide by an automatic arrangement, so that the yield of gas is regulated, but the gas continues to be evolved after the water-supply is shut off, since the moistened carbide cannot be prevented from undergoing decomposition. In others, the carbide is introduced into 10 times its volume of water in a vessel connected with a gas-holder of sufficient capacity.

Whether acetylene is likely to have a great field in the future, cannot in the present state of development be predicted, but many changes and improvements are necessary before it can be looked upon as having any great practical value.

Gasolene gas is a mixture of gasolene vapor and air, the function of the latter being to dilute the former until the proportion of carbon in the mixture is equivalent to that in common gas. Gasolene is a mixture of light hydrocarbons, a product of the distillation of crude petroleum. Its specific gravity ranges from 0.629 to 0.667. It volatilizes slowly at low temperatures and rapidly at 70° F. and above. It is exceedingly inflammable.

Gasolene gas is generated and forced through supply pipes to the burners by special forms of apparatus which require but little attention. It is well suited to single houses and small groups of houses where no public supply exists.

Impurities Given off in Lighting.—In the combustion of illuminants of all kinds, considerable amounts of decomposition products are given off to the air, and their removal by means of efficient ventilation is important. These products are least in amount and importance in lighting with candles and oil lamps, being chiefly carbon dioxide and watery vapor. The impurities given off in the combustion of gases include sulphur dioxide, very variable in amount according to the extent of purification; carbon monoxide, also variable according to the completeness of combustion; carbon dioxide; ammonium compounds, and aqueous vapor.

Gas Pipes.—Street mains are commonly made of cast-iron pipes of rather light weight, which vary much in texture and density, and not infrequently are perforated with blow-holes of varying diameter or otherwise defective. On account of the dangers of extensive leakage and of the financial loss due to waste of gas and the cost of making repairs, all pipes should be tested thoroughly before being laid. Pipes which show no leaks when new may soon be corroded in the soil at points where bubbles occur in the walls with but a thin layer of metal on either side. Wrought-iron pipes are corroded more quickly in the soil, but are more uniform in density and texture than cast-iron and require fewer joints in a given distance. Both kinds should be protected by a generous coating of asphaltum or other suitable material.

House pipes are most commonly of wrought iron, though sometimes softer materials are employed. The latter are more expensive, and

possess the additional disadvantage of being easily punctured by nails and gnawed by rats and mice. The entire system of distributing pipes should be joined most carefully, in order that no leaks shall occur. When they do occur, the search for their location should be conducted with all possible precautions against risk of explosions, since mixtures of gas and air in the proportion of about 8 per cent. of the former are violently explosive if brought in contact with a flame. The gas should be shut off at the meter, and the apartments where the smell is perceived should be aired thoroughly. The examination should then be begun at the meter and its connections, and if defects are there found, the meter, if at fault, should be removed, or the connections put in proper condition with new washers. The fixtures should next receive attention, every joint and cock being tested, the gas being turned on again at the meter. Smearing the joints with some viscid material, such as strong soapsuds, will show small leaks by formation of bubbles. The examination of the joints of the distributing pipes is a matter of considerable difficulty, and may require much disturbance of structural parts.

Fixtures should be so located as to avoid hot-air currents from registers in the floor and walls, on account of the great annoyance caused by flickering of the flame. Flickering is caused also by the presence of condensed moisture in sags in the pipes and bends in the fixtures, which causes the gas to issue in a series of bubbles with consequent unsteadiness of the flame. The remedy consists in interposing drip cups and draining off the water.

The proper arrangement of fixtures is frequently a difficult problem, particularly in large rooms. In general, it may be said that they should be well distributed rather than clustered in central chandeliers. Fairly uniform diffusion may be secured by the use of globes of prismatic glass, which act in the same way as the ribbed and prismatic window glass described above.

Electric Lighting.—Incandescent electric lighting possesses certain notable advantages over all other systems of artificial illumination. It requires no oxygen and produces no decomposition compounds, and hence in no way alters the composition of the air. It imparts but little heat to the surrounding air, and hence has but a limited influence in causing convection currents and raising room temperature.

Section 4. PLUMBING.

Whether we view the subject from the standpoint of possible danger of infection through inhalation of sewer air or from that of æsthetics, we should recognize the great importance of the removal of all sewer wastes from the habitation through a system of plumbing that is so perfect that it shall leak neither liquid nor solid matters, nor foul air and smells. For the attainment of the best results, all large communities adopt plumbing ordinances designed to prevent faulty construction and the admission of the dreaded "sewer gas," which, to the lay

mind, and very generally to the professional mind as well, is a most potent cause of disease. While the weight of evidence is against the acceptance of the doctrine of the transmission of disease through this agency, it must be conceded that foul odors, besides being disagreeable, exert on the sensitive individual a decidedly injurious action through the imagination, and, more particularly, through their effects on the appetite and digestion. Most of the foul smells coming from plumbing fixtures are not from the sewer at all, and hence may not properly be called sewer gas or sewer air; they are due to decomposing organic matters within the pipes or traps, or in some other part of the fixture, which, with ordinary use, does not become thoroughly cleansed. Thus, it is often found that the odor from a wash-basin is due to decomposing soapy matters and other deposits in the horn leading from the overflow holes, but it is difficult to convince the timid that such is the fact, except by ocular and other demonstration.

The most perfect system of plumbing needs careful supervision, for no pipe or other part subjected to frequent contact with filthy matters can be kept permanently clean unassisted; and any such surface not cut off from contact with the free air of the room must inevitably, under certain conditions, give rise to a certain amount of nuisance. The reduction of these possibilities for nuisance to the lowest limits is one of the main objects of the many ingenious plumbing appliances of one kind and another that are almost daily increasing in number and variety.

Broadly speaking, plumbing may be divided into two classes: good plumbing and bad plumbing. The former costs more in the beginning; the latter, in the end; the former is installed by the capable and honest plumber; the latter, by the trickster who has given his calling such a bad name that he finds it more to his liking to hide behind the more pretentious title of "sanitary plumbing engineer," just as some barbers become "tonsorial artists."

The better class of plumbers, in undertaking the installation of a system of plumbing, attempt to attain such a degree of perfection that repairs are only occasionally necessary; the other class, either intentionally or because of inability to do good work, produce a system requiring constant repairs and consequent expenditure. This class of workmen also are quick to take every advantage of loosely drawn or ambiguous specifications, whereby the owner suffers eventually more than the original financial injustice. But the responsibility for poor plumbing is not by any means always to be placed upon the plumber, for an owner unwilling to pay the price of good work can hardly blame the plumber for unwillingness to provide labor and first-class material at less than cost, and so gets cheap material and cheap workmanship in return for his inadequate appropriation.

A good system of plumbing calls for sound materials, absolutely tight joints, thorough ventilation, and a plentiful water supply to insure thorough flushing without wastefulness. It should be so planned that the various fixtures on each floor shall be in relatively the same

locations, thus avoiding unnecessary and expensive extensions of waste and supply pipes. The wastes should be easily accessible, and are best run in full view, so that any leakage may be detected at once. When hidden from view, leaks may exist undetected until much damage has resulted. Open plumbing, furthermore, insures good workmanship, and makes repairs simpler and much less expensive. The pipes need not be a disfigurement to a room, for they may be neatly painted or bronzed, and will then have no worse appearance than those used in steam heating. If they must be placed in recesses or within walls, they may be concealed by boards or panels fastened by screws, and easily removable.

The important fixtures, such as bathtubs and water-closets, should be placed where ventilation can be secured and where dependence upon artificial light is not altogether necessary. The ideal place is in an outer room with a window through which the sun's rays and fresh outdoor air may enter.

The Soil-pipe and Main Drain.—The soil-pipe receives at various points, through the several waste-pipes, the contents of wash-bowls, sinks, bathtubs, urinals, water-closets, and other fixtures, and conducts them to the drain, by which they are carried on to the sewer or cesspool, as the case may be. In this country, the material almost universally used for soil-pipe is cast iron; but in England lead is preferred. The advantages of iron over lead are many; it is lighter, stiffer, stronger, cheaper, and more durable, and is not subject to accidental perforation by driven nails and gnawing rats. Lead pipe of large diameter sags by reason of its weight, and it is difficult to secure it strongly wherever its weight is borne by the fastenings. It is very easily corroded, dented, flattened, and perforated.

Cast-iron soil-pipe is made in two grades; light, or "standard," and "extra heavy." Only the latter should be employed, the former being much too thin and flimsy. The walls of the extra heavy grade should not be less than an eighth of an inch in thickness. The pipe is made in lengths of five feet, exclusive of the socket, or hub, which is an enlargement of one end for the reception of the spigot end of the next length, so that no irregularities shall be caused in the caliber of the pipe where joints occur, but, on the contrary, that the inner surface shall be flush throughout. Each length should be of uniform wall thickness throughout and free from flaws, sand holes, and other imperfections, and should be subjected to strength tests at the place of manufacture. The inner surface should be perfectly smooth.

In joining the lengths together, the spigot end of one is inserted as straight as possible into the hub of the next, and a gasket of oakum is inserted into the intervening space by means of a caulking tool, and rammed hard so as to fill about half the depth of the hub. The object of the gasket is to prevent the entrance to the bore of the pipe of any of the molten lead used in the next process. The next step is the filling of the rest of the space with molten lead from a ladle. Since this metal shrinks on cooling, and since moisture and dirt prevent its

adherence to the iron, it is necessary next to expand it and drive it down by mechanical means. This process requires care and involves much risk of fracture, since the blows of the caulking tools must be quite heavy; in fact, much heavier than the lighter grade of pipe can withstand. Against this form of pipe and its jointing, certain objections are urged, not the least of which is the opportunity given for botch-work and fraud. Instances of filling the space with mortar, sand, putty, and other material have been not uncommon. Some unscrupulous plumbers gloss over the fraud with a thin layer of lead; some make the joint properly and neglect to caulk it; some make as perfect a joint as possible in places where ocular inspection is easy and probable, and omit to caulk, or even to insert the oakum, where the joints are hidden, but without forgetting to make the usual charge.

Another objection to this form of joint is the possibility of its becoming loose through alternate expansion and contraction due to changes in temperature. The expansion is unequal, especially when due to hot water in the pipe, and the spigot expands more than its surrounding socket and compresses the interposed lead, which, when equilibrium becomes reëstablished, does not resume its original shape, but remains in its new form. In this way, it is possible, but not very probable, that a minute space may be created all about the spigot, and that through this space, leakage of liquid, but more especially of air, may occur. In an upright pipe, leakage of liquid is most unlikely to occur, since the hub end of each joint is uppermost.

Still another objection is the great difficulty encountered in unjointing, when, for any reason, it is necessary to remove a length of pipe in making repairs and alterations. The usual and easiest course to pursue in such a case is to break the pipe and remove it in pieces.

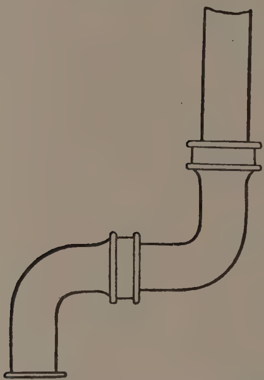
To meet the several objections to this form of pipe, the Sanitas flanged pipe was devised by Mr. J. Pickering Putnam, of Boston. This makes a joint which is described as an adjustable flanged joint with lead washers or gaskets for packing. The gaskets, which are star-shaped in cross-section, are squeezed between the flanges of the two adjoining pipes and crushed to half their original thickness by screwing up the bolts set in square recesses in the flange ears. These are screwed simultaneously, so that the pressure on either side is equalized and the gasket is compressed uniformly. The gasket for a four-inch pipe weighs a half pound. For this joint, are claimed cheapness and security. The time required to make it is reckoned in seconds as against minutes, the amount of lead consumed is much less, and the unjointing is simple and involves no breakage.

The diameter of a soil pipe should ordinarily not exceed four inches, but in very large buildings, in which are numerous water-closets and other fixtures, five-inch pipe is sometimes used.

Soil pipes should run as nearly vertically and with as few deviations from a straight line as practicable. When these are necessary, right-angled bends, such as are shown in Fig. 47, should be avoided, and instead thereof, obtuse-angled elbows, as in Fig. 48, should be em-

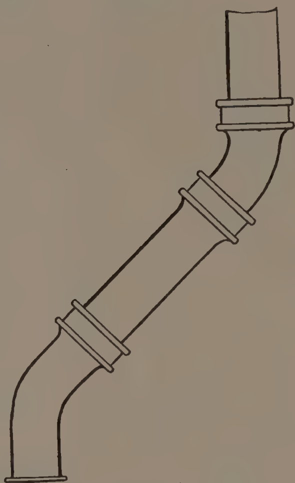
ployed. Where waste-pipes and branches connect, the junctions should be made with Y-branches and not at right angles. (See Fig. 49.)

Fig. 47.



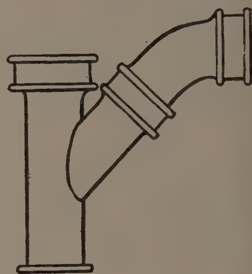
Improper bends in soil-pipe.

Fig. 48.



Proper bends in soil-pipe.

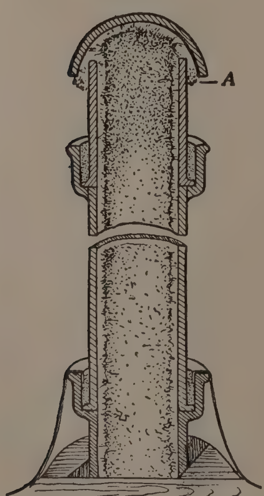
Fig. 49.



Y-branch to soil-pipe.

These junctions are made differently when a lead pipe is to be connected with an iron one. The lead pipe is first "wiped" on to a brass ferrule by means of solder, and then the ferrule is caulked into the hub. With the flanged Sanitas pipe, the connection is obtained more easily and cheaply; here the lead pipe is flanged out and bolted to the iron by means of cast-iron rings with ears and bolt-holes corresponding to those on the pipe.

Fig. 50.



Occlusion of outlet of soil-pipe by frost.

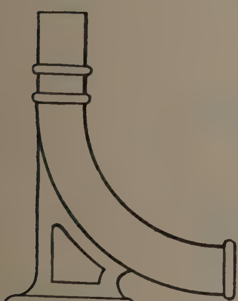
Each soil-pipe should be extended in full size through the roof for about two feet, and its outlet should not be obstructed by a cap or cowl, as is commonly done. The cap serves no useful purpose, and the passage for air is so narrow that, in winter, when the warm, moist air ascends, a coating of frost is formed all over the inner surface of the exposed pipe, and this may grow in thickness so as to occlude the outlet completely, as is shown at *A* in Fig. 50. In all cases, one should make provision for the expansion and contraction of the column of metal, for while the movement either way is slight, its force is very great; therefore, the fastenings should not be too rigid, but should allow a little play.

The soil-pipe should be very firmly supported at the bottom, and

its junction with the main drain should be made with a bend of as large a radius as possible. The best support is either a brick pier or a wooden post, or other firm and unyielding structure. The connection should under no circumstances be at a right angle, but with an elbow bend supported on a foot, as in Fig. 51. If the pipe must be carried along a cellar wall, it should be supported either by a shelf or by wrought-iron pipe-hooks.

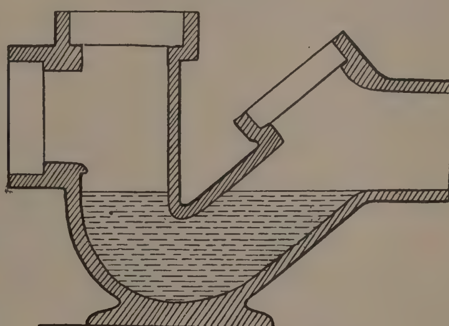
From the point where the soil-pipe departs from the perpendicular and tends toward the sewer or cesspool, it is commonly known as the drain, whether other soil-pipes enter it or not. The drain should consist of iron as far as a point well away from the foundation of the house and from all danger of fracture due to settling. Under no circumstances should an earthenware drain-pipe be employed within the house or beneath the foundation, or through a soil in which a well of drinking-water is situated. The main drain may be carried along the wall of the cellar in the manner above described, or it may be suspended by wrought-iron hangers from the joists of the floor of the first story;

FIG. 51.



Elbow bend and support.

FIG. 52.



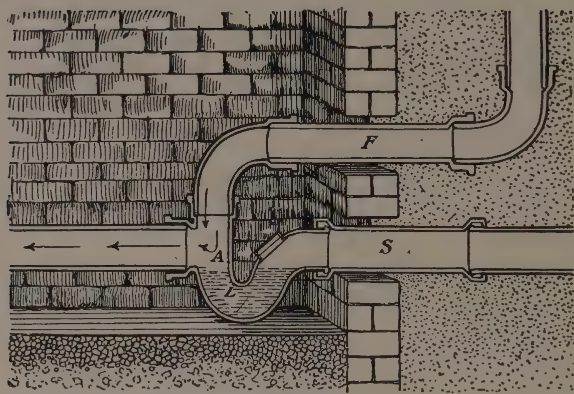
Intercepting trap. (Running trap.)

or, if there are water-closets or other fixtures in the cellar, it may run below the floor. In the latter case, it should be easily accessible.

The drain should have all the fall that can conveniently be given, and this should be as nearly uniform as possible throughout its length. No part of it should run flat or sag. The greater the pitch, the more completely the pipe is scoured out by each passage of water. It should have a fall of at least a quarter of an inch to the foot, or, preferably, more.

Before the drain passes beneath the foundation wall, or, if this is impossible, at a point outside in a manhole, an intercepting trap is placed, provided with clean-out holes covered with air-tight covers. This trap, known sometimes as the running trap and main trap, is of the same diameter throughout as the drain itself. This kind of trap is manufactured in an immense variety of forms, one of the best of which is shown in Fig. 52. This has an inlet and an outlet for sewage, an inlet for fresh air, and a clean-out and inspection hole on the

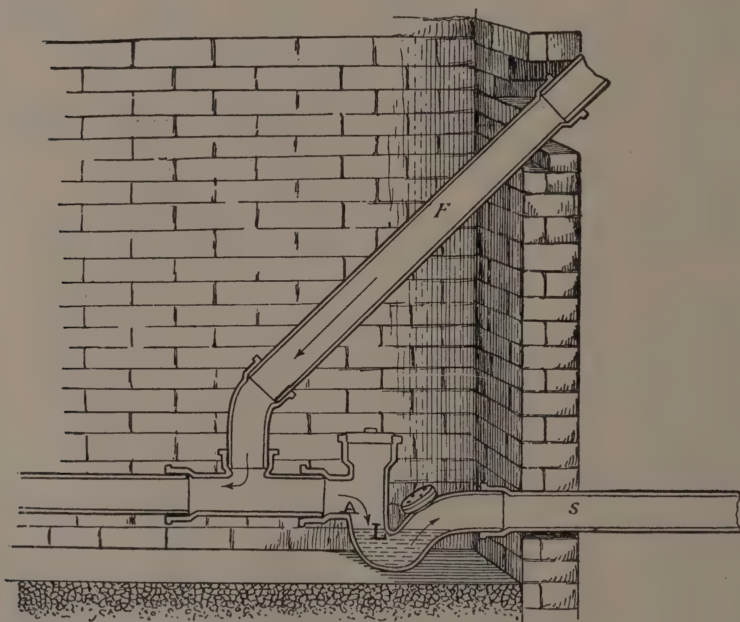
FIG. 53.



Objectionable arrangement of intercepting trap and ventilating pipe.

outfall side. The sewage enters by the inlet at the left, which is slightly higher than the outfall at the right. The uppermost opening

FIG. 54.



Preferable arrangement of intercepting trap and ventilating pipe.

is for the fresh-air inlet. The latter is for the purpose of insuring a complete circulation of fresh air throughout the entire length of the drain and soil-pipe, and communicates with the external air by means

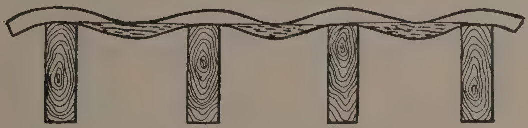
of a pipe of the full diameter of the drain, running from the house side of the trap to some point outside.

In Fig. 53 is shown an arrangement very commonly adopted, but open to serious objections. Here, the filth may be thrown up against the entrance of the fresh-air pipe F at A and form an accumulation. The floor of the drain and of the outlet S are at the same level, as is shown by the two sides of the water seal L, and there will be, therefore, not head enough to force all light solids easily beneath the dip of the trap.

A much better arrangement is that shown in Fig. 54. In this, the inlet of the fresh-air pipe F is situated at a point some distance away from and on the house side of the trap, where splashing and accumulation of filth cannot occur. At A, the entering sewage falls through a distance of about two inches at L, and can force any solid matter under the dip and onward through S. It will be noted by the direction of the arrows in both figures that the normal direction of the air current is inward, but under some conditions of internal and external temperatures, as, for example, in summer, the direction is likely to be reversed. In winter, owing to the higher temperature of the house, the movement in the soil-pipe is naturally upward and outward, and in the pipe F is downward and inward.

Waste-pipes.—The pipes connecting fixtures with the soil-pipe are known as waste-pipes. They are made commonly of lead, although cast-iron, wrought iron, and galvanized iron are employed also. The

Fig. 55.



Sags in an improperly laid pipe.

advantage of using lead is that it is more easily run, especially in places where bends and angles are necessary, and requires, therefore, a smaller number of joints. The disadvantages are the liability to perforation by nails carelessly driven and by gnawing rats, and the possibility of the formation of air-locks through sagging of a pipe improperly laid. These occur sometimes when a pipe is not properly supported or where high points and low points occur in a crooked run. This is shown in exaggerated form in Fig. 55. Here we see a series of low points, in which water will stand and where sediment may accumulate, and a corresponding number of high points containing air. These impede the flow of water onward, and if the pressure is low, a series of them in a single run may stop it altogether.

Iron pipes possess whatever advantage attaches to rigidity, and while they are not so easily adapted to crooked runs and require more joints, it must be said that the latter are made quickly and easily when screw couplings are employed. Some joints are made by screw-

ing directly into hubs and some by means of ordinary couplings, the result in either case, as shown in Fig. 56, being perfectly flush fittings.

Ordinarily waste-pipes need not be larger than 1.5 inches in diameter, nor heavier than three pounds to the foot. In those cases where the supply pipes deliver a heavy stream of water under high pressure, it may be necessary to use a larger size, in order to insure the removal of all the water without danger of overflow. Too large pipes and too

Fig. 56.

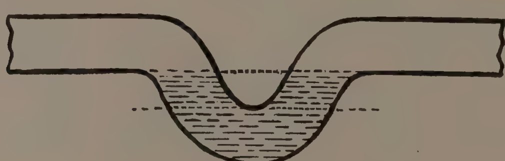
Flush fittings with screw couplings.

small pipes are equally bad. If too small, the overflow is retarded and they are choked easily; if too large for the fixture from which they lead, they cannot possibly be flushed thoroughly, but are soon coated with grease and other filth, and eventually become completely occluded. Thus, a 2-inch waste-pipe, attached to a fixture by a 1.25-inch joint, would be quite too large and out of place.

Lead waste-pipes may be joined to iron soil-pipes in the manner already described, and to wrought iron by brass screw nipples wiped on to the lead with solder and screwed with red lead into the thread of the fitting. Lead should always be joined to lead by wiped solder joints, and never by cup or "copper bit" joints, excepting when the operation of wiping is clearly impossible.

Traps.—Each separate fixture connected with the soil-pipe, that is to say, each water-closet, wash-bowl, bathtub, etc., should be provided

Fig. 57.

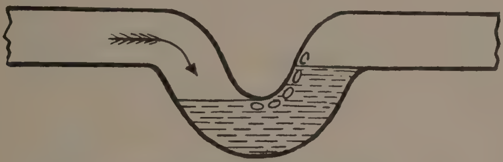


Running trap.

with some form of trap situated as near it as possible. A good trap will wholly prevent the passage of all air or gas or odor from the waste-pipe or soil pipe backward into the air of the house, while per-

mitting the free passage of liquids and suspended solids toward the sewer. It should be of such construction as will admit of ready inspection and cleaning, and under ordinary circumstances should be self-cleansing. Improperly trapped or untrapped fixtures are as much to be avoided as leaks, the result in either case being the same so far as the passage of offensive odors is concerned.

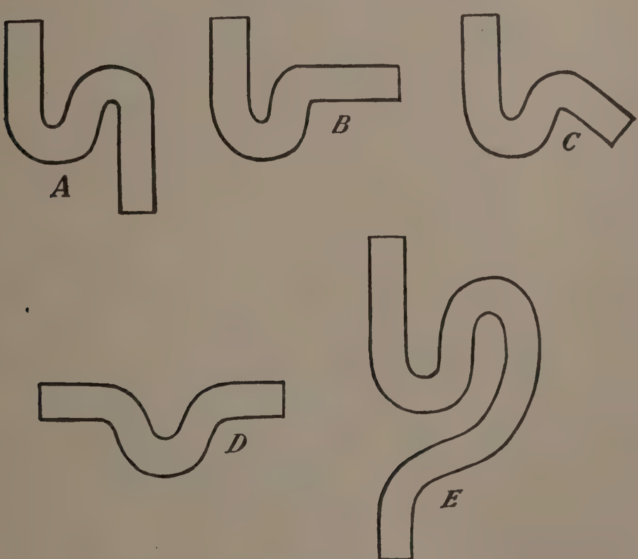
Fig. 58.



Forcing of seal of running trap.

The simplest form of trap, called *running* trap, consists of a downward bend in a horizontal pipe, as shown in Fig. 57. When water is discharged through such a pipe, the depressed portion will be found to stand full of water when the discharge ceases, and this body of water

Fig. 59.



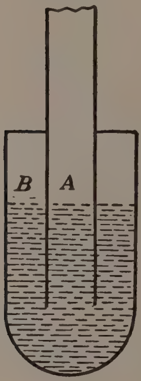
Forms of round-pipe traps.

will prevent the passage of air in either direction; but if sufficient pressure is exerted on either side to force the level of the water on that side down to the lowest point of the bend, air may be forced through, as is shown in Fig. 58. The water between the water level and the

lowest point of the upper internal surface of the bend is known as the seal, and this should never be less than 1.5 inches in depth. In Fig. 57, the seal is that which lies between the dotted lines. This form of trap is one of a class called *round-pipe* traps, and to this class belong a number of forms, five of which are shown in Fig. 59. These are the *S-trap* (A), the *Half-S* (B), the *Three-quarter S* (C), the *Running* (D) already described, and the *Double-S* or *Hunchback* (E). These several forms are in all cases of the same size throughout and, therefore, will pass anything that can gain entrance. With proper flushing, they are easily kept clean, but they are quick to lose their seal by a sudden flow of water through them or by disturbance of atmospheric pressure produced by the sudden discharge of water through pipes with which their own pipes are connected. The means for the prevention of this occurrence are considered below.

Another class of simple traps includes all those known as *Bottle* or *Pot* traps. In one form of the bottle trap, the principle of which is shown in Fig. 60, the end of the inlet-pipe dips several inches into the pool of water. In order to drive air backward through the inlet-pipe A, it would be necessary to exert pressure sufficient to force the water within the chamber B upward through A until its level is brought down to the lower end of A. Under ordinary circumstances, such a pressure would be quite impossible. To drive air in the other direction through A into B is less difficult, but this will require a pressure sufficient to depress the water standing within A down to the outlet of the pipe.

Fig. 60.



In Fig. 61 is shown a trap of this kind, in which there are two inlets; the principal one, the pipe I, and the second, which connects with the overflow of the fixture, the pipe B. The arrows indicate the direction of movement of the sewage through the pot. As the level rises, the excess runs off through the outlet O and discharges downward. The upper portion of the pipe marked V connects with the ventilating pipe, in which free circulation of air is maintained. The object of this is explained below. This form of trap is made to lose its seal only with great difficulty, although a part of it may be lost by siphonage. The objection to this form of trap is the likelihood of the accumulation of filth, for, unlike the round-pipe trap, they are not self-cleansing, since the whole contents are not set in motion each time the fixture is used.

Another, simpler, form of pot-trap is that shown in Fig. 62. Here the inlet-tube I is not immersed in the liquid, but communicates directly with the lower part of the chamber; the outlet O starts from the upper part of the chamber, and the communication with the ventilating pipe has its exit at the crown. It will be observed that in both these forms the seal is quite deep. The undue accumulation of filth in these traps should be guarded against, and for this purpose

clean-out holes, closed with metallic screw-caps, are provided. A large accumulation of filth in one of these traps makes siphonage of the seal more easily brought about. This class of trap is used only under sinks, basins, baths, and washtubs; never under any circumstances under water-closets.

FIG. 61.

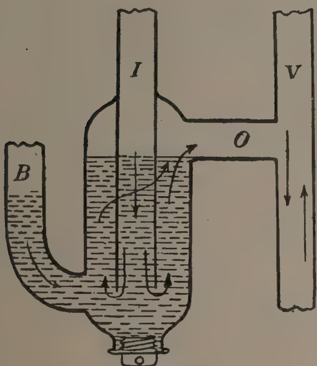
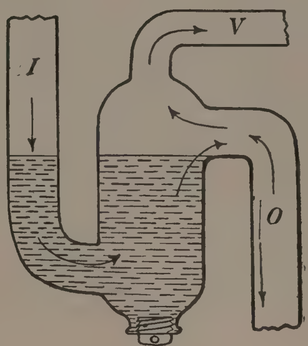


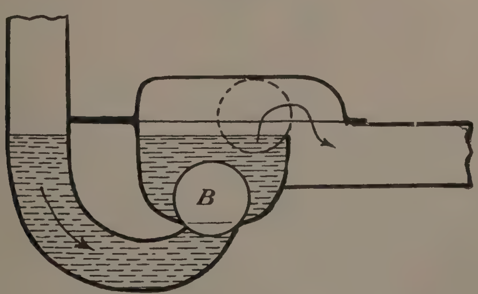
FIG. 62.



Two forms of ventilated bottle traps.

Among the traps depending upon mechanical devices to assist the water-seal, the *Ball-trap* may be taken as a type. In this form (shown in Fig. 63), the up-cast limb of the trap consists of a chamber considerably broader than the inlet branch, and contains a ball, the specific gravity of which is slightly greater than that of water. This, when

FIG. 63.



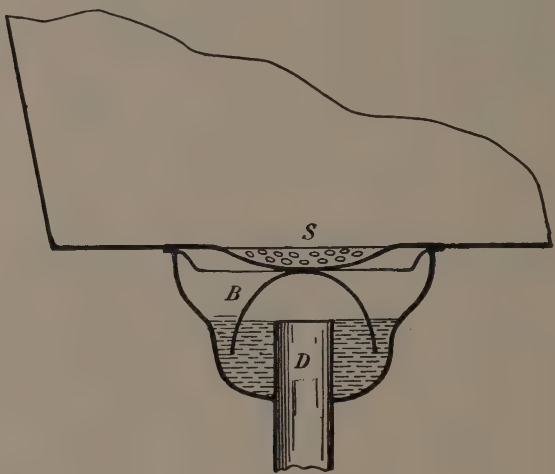
Ball-trap.

the contents of the trap are at rest, rests on its seat and makes a gas-tight joint. When liquid is discharged into the trap, the ball *B* is thrown upward into the position indicated by the dotted line; and when the flow ceases, it drops into its original position. It cannot escape from the chamber, since there is not space enough for it to

pass between the lip of the pot and the top of the cover. This form of trap cannot be siphoned out, because of the size of the pot, but, with disuse, it may lose its seal by evaporation. In such an event, however, the ball retains its seal and closes the joint. The great objection to this trap is that, even although nothing which should otherwise be disposed of is thrown into the fixture, as, for instance, matches and other objects, the seat of the ball is likely to become the point of deposit for hair, bits of cotton, linen fiber, and sponge, and then a gas-tight joint cannot be made with the ball. As a matter of fact, indeed, all mechanical devices in traps are much inferior to the ordinary water-seal.

Another form of trap, much used in kitchen sinks, is known as the *Bell trap*. (See Fig. 64.) In this, the delivery pipe *D* projects for

Fig. 64.



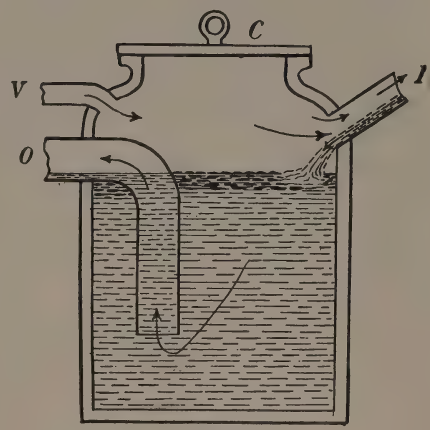
Bell trap.

some distance upward into the reservoir; the inlet consists of a strainer, *S*, to which is attached the bell *B*, which dips into the pool of water in the reservoir and encloses the outlet of the pipe *D*. There is, it will be seen, no direct communication between the air contained within the bell and that above. The waste reaches the reservoir through the holes in the strainer, and as the level of the liquid rises, it escapes through *D*. This form of trap is quite likely to be choked by deposits of small bits of food material and other substances forced through the holes of the strainer with the aid of a sink brush. It is also easily siphoned, and, furthermore, being easily removed, it happens very commonly that the fixture is utilized by lazy servants for the disposal of waste matters which should be deposited elsewhere.

Grease traps are devices for preventing the choking of drains by

grease, which, discharged in the liquid state with hot water, solidifies when it comes in contact with the cold surface of the waste-pipe and adheres thereto with great tenacity. The coating which it forms becomes thicker and thicker through successive applications, and eventually may occlude the pipe so completely that the trouble must be attacked from the outside, the remedy requiring sometimes the removal and incidental destruction of an entire length of pipe. Grease traps may be located beneath the sink or, preferably, in a place provided therefor outside the house.

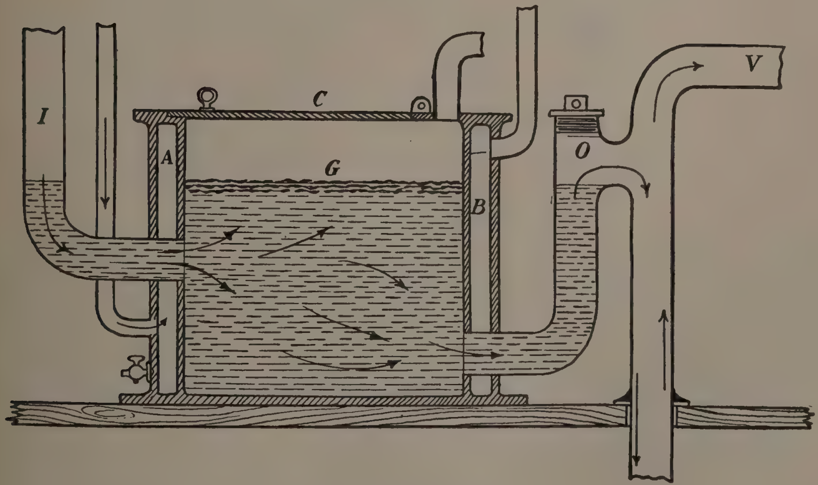
FIG. 65.



Grease trap.

A common type of this device is shown in Fig. 65. The greasy water runs into the reservoir through the inlet *I*, and the liquid grease, being lighter than the water, rises to the surface and forms a scum, which, when cold, solidifies into a cake. The outlet *O* of the trap dips far beneath the surface, and so discharges none of the

FIG. 66.



Jacketed grease trap.

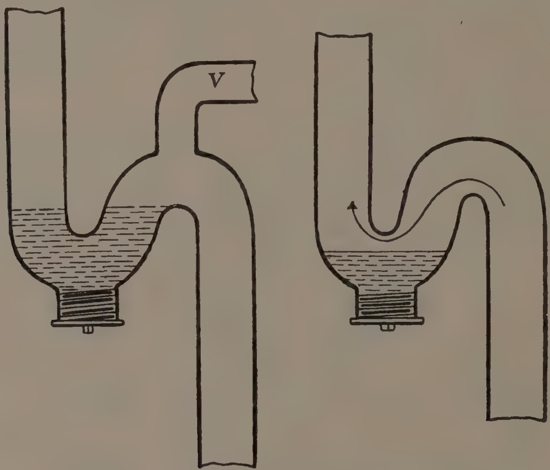
accumulated grease. Air is admitted through *V*, and can circulate thence through the inlet pipe *I*, as indicated by the arrows. The accumulated grease should be removed periodically through the clean-out,

which is closed by the cover *C*. A larger and more complicated apparatus is shown in Fig. 66. Here the chamber is enclosed in a jacket, *A B*, through which cold water is allowed to circulate. The dirty water enters through *I* and discharges from the upper branch *O*, which is vented through *V*. The grease accumulates at *G*, and is removed through the top, which is closed by the hinged cover *C*.

There are many other forms of grease interceptors, but none is perfect, for under the most favoring circumstances some grease will escape and may congeal on the surface of the waste-pipe or drain. All grease traps should be attended to at short intervals, else they may become almost completely filled with solid grease.

Loss of Seal.—Traps may lose their seal in various ways: by siphonage, by evaporation, by back pressure, by leakage, by accumulation of sediment, and by capillary attraction. The most important

FIG. 67.



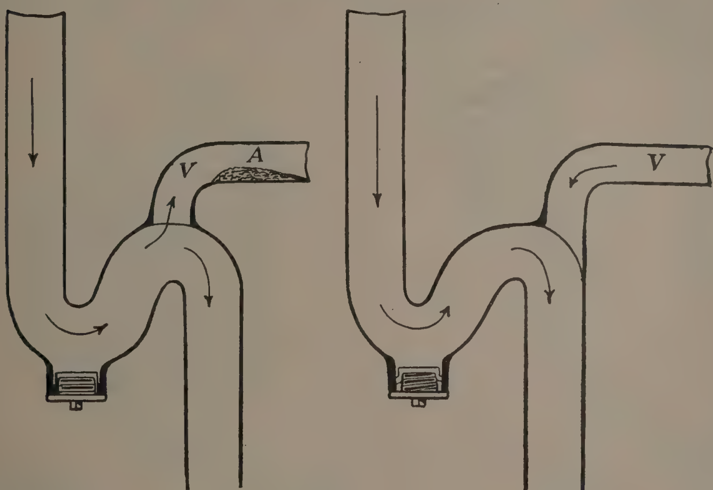
Effects of ventilation and non-ventilation of traps.

of these is siphonage, for the prevention of which two methods commonly are employed. In one, the up-cast limb of the trap is widened so that it becomes a pot or reservoir. A large reservoir will resist siphonic action much more successfully than a small one; an 8-inch pot cannot be siphoned through a pipe of ordinary size, a 4-inch pot resists only when its seal is unusually deep, and anything less than 4 inches is inadequate.

This form of trap, however, offers decided objection. In the first place, it is likely to accumulate much sediment; and in the second, it constitutes a miniature cesspool, the presence of which in a system of plumbing should not be countenanced, since sewage matter should be discharged in as fresh a condition as possible, and not in a state of putrefaction, which, if cesspools are employed, will inevitably be

brought about. Moreover, this form of trap is very expensive and bulky. In the other method, the up-cast branch is connected with a ventilating pipe by a branch from its upper portion. Unless one or the other of these two methods is adopted, the contents of the trap, particularly in the case of a round-pipe trap, are likely to be siphoned over when its fixture is used or when a large volume of water is discharged from some other fixture into the soil-pipe, and in its descent causes a partial vacuum. In the former case, the trap is self-siphoned; in the latter, the partial vacuum draws the water over and breaks the seal. If the trap communicates with a ventilating pipe, this disturbance of equilibrium cannot occur, since the descending mass of water causes a downward suction of air through the vent pipe to satisfy what would otherwise be a partial vacuum. In Fig. 67, the diagram

Fig. 68.



Improper and proper positions of vent pipes.

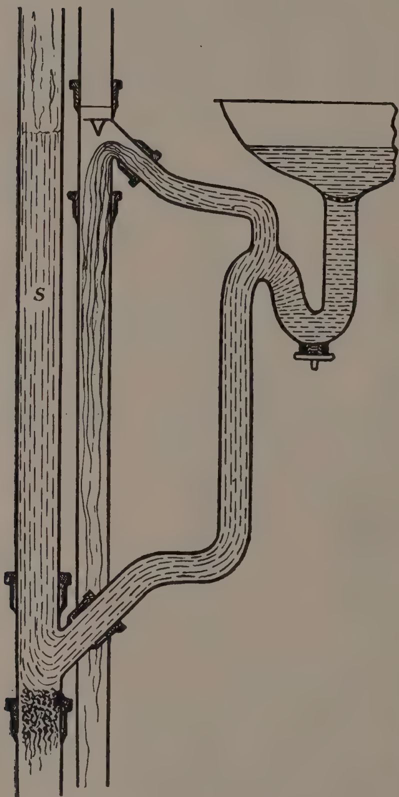
on the right shows the condition after siphonage has occurred; the greater part of the water has been drawn over until air can be sucked through, and that which remains has fallen back into place. The result is that a free communication exists between the fixture above and the soil-pipe below. The diagram on the left shows the condition of the seal if the trap is connected with a ventilating pipe through *V*.

In venting traps in this way, the position of the vent pipe is of considerable importance. Ordinarily, it is placed as shown in the figure. The objection to this procedure and the proper method are shown in Fig. 68. If the pipe enters in the middle of the bend, each discharge of sewage into the trap causes a projection of the liquid upward into the pipe *V*, and after a time an accumulation is likely to occur at *A*. If the pipe is situated farther to the right, as in the drawing on the right, this accumulation is not likely to occur, and

the sewage and the air take the directions indicated by the arrows. The vent pipe is more easily joined to the trap, however, in the manner to which objection is made.

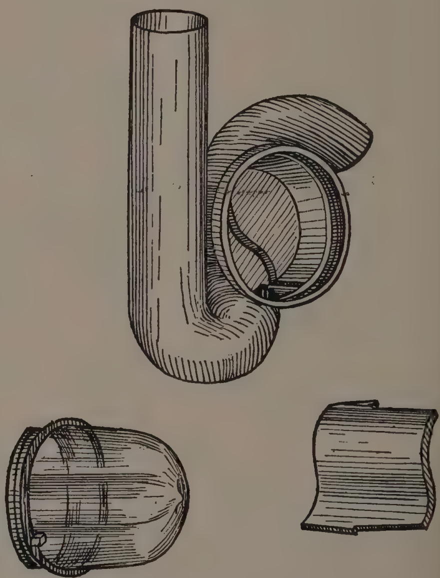
The ventilating pipes from the different traps of a system of plumbing connect with a main ventilating pipe, which may be joined to the soil-pipe, alongside of which it runs, at a point in its upper part, before its projection through the roof. It is important that the junction of each vent pipe with the main shall be at a point above the fixture, since, in case of an obstruction in the soil-pipe below, the water may back up through the trap and discharge through the vent pipe into the main vent, as shown in Fig. 69. Here, the soil-pipe *S*

Fig. 69.



Improper junction of vent pipe with main vent.

Fig. 70.



Sanitas trap (taken apart).

has been obstructed at a point just below the entrance of the waste-pipe from the fixture, and water has accumulated throughout the entire length of waste-pipe and is discharging into the main ventilating pipe at V. If the point V were higher than the upper margin of the bowl, this could not occur, since the bowl itself would fill and overflow into the room, and thus call attention to the obstruction.

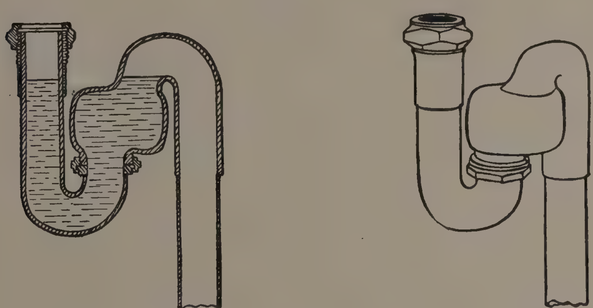
Non-siphoning Traps.—A number of traps known as *non-siphoning* have been devised to obviate the necessity of back-venting. Among

these may be mentioned the "Sanitas," invented by Mr. J. Pickering Putnam, and the "Hydric."

The Sanitas trap, shown in Fig. 70, is made proof against siphonic action by a deflecting partition within the chamber, which permits the passage of air above the water and throws back a volume of water sufficient to maintain a seal over three inches in depth, which resists evaporation for a long time and cannot be destroyed by capillary attraction. When attached to fixtures with large outlets and quick discharge, it is also self-cleansing, even when ashes and similar unusual constituents of sewage are thrown into it. In the figure, the several parts are shown separately: the main structure, the chamber, and the deflecting partition.

The Hydric trap, shown in Fig. 71, contains no deflecting partition or other mechanical device, but depends upon the action of the upper surface of the body of the trap in deflecting and throwing back the water during the sucking of the air through the chamber and over the

FIG. 71.



Hydric trap.

water. When the siphoning action is finished, a sufficient volume of water remains to form a permanent seal.

Evaporation of the seal does not commonly occur except after long disuse. It is favored by trap ventilation, since, when a current of air comes in constant contact with a body of water, constant absorption is in process. In order to prevent loss by evaporation in case of long disuse, two processes are in vogue. One is to employ a trustworthy person to visit the premises weekly during the absence of the occupants and flush each fixture. The other, and, on the whole, the more economical, is to pour into each fixture a sufficient amount of glycerin, which, being hygroscopic, will take water from rather than yield it to the atmosphere, or of oil, which will float on the surface of the water and prevent its absorption by the air.

Back pressure is a force which is not much to be feared. In former times, when it was not customary to ventilate the soil-pipe, back pressure was caused not uncommonly by winds and the action of tides, so that the air in the whole plumbing system was compressed and the seal

forced backward. Sometimes, a trap situated near the bottom of a tall stack is forced by back pressure, brought about by the descent of a column of water pressing the contained air ahead of it.

Leakage as a cause of loss of seal is too evident to require explanation. Accumulation of sediment may be so extensive as to replace the water in great part, and thus render siphoning much easier. Capillary attraction is a not infrequent cause of loss of seal when accumulations of hair, threads, and other like substances occur in a non-scouring trap at the outlet and drain away, little by little, the fixture side of the seal into the outfall.

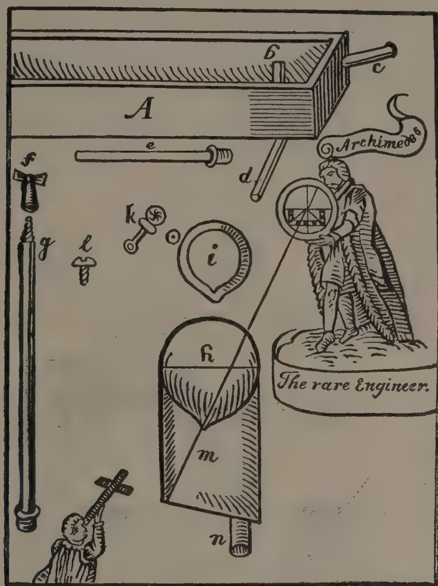
It is hardly necessary to say that nothing should be thrown into traps excepting those matters which are recognized as constituents of normal sewage, that is to say, neither matches, nor rags, nor broken china, nor wads of newspaper, nor stiff writing paper not easily disintegrated by the action of water. All such substances are likely not only to clog traps and break the seal, but also to form obstructions in soil-pipe, particularly where bends occur.

The extremists who cling to the sewer-air theory of transmission of disease are not always satisfied with ordinary trapping, feeling sure that the water in one branch of the trap will absorb disease germs from the sewer air and discharge them on the fixture side. To avoid this, a system of double trapping has been advocated, with which assurance is made doubly sure. With this arrangement, we have two traps in immediate succession, so that the waste from the first must pass through the second; thus we have two seals, and any poison absorbed from the farther one and disengaged backward will then meet with a second obstruction. Besides the manifest absurdity of such extreme precaution, there is a decided objection to this arrangement, since solid matters are likely to lodge in the second trap and cause it to be obstructed. While the head of water may be sufficient to drive the waste through one trap, it is by no means certain that it will be strong enough to drive it through two, and, as a matter of fact, it usually is not. Moreover, between the two traps an air lock is likely to form, and that in itself is a decided objection, as has been explained.

Water-closets.—By reason of the fact that their general employment is a matter of comparatively recent times, it is believed very commonly that water-closets are the invention of the last half century. They date back, however, many centuries, for in a somewhat simpler form they were in use in ancient Rome and Pompeii, and probably even earlier in Asia and Africa. These primitive forms, however, were devoid of the mechanical appliances, flushing tanks, etc., of the closets of the present day. It is said that the prototype of the present closet was in use in France and Spain before the sixteenth century, but, so far as is known, no diagrams of their construction are extant. In England, the first water-closet with a flushing apparatus was constructed under the direction of Sir John Harington, at his country seat at Kelston, near Bath, and described by him in a satirical, semi-political work, "An Anatomy of the Metamorphosed Ajax," printed in 1596,

from which work Figs. 72 and 73 are taken. Fig. 72 shows the details of the apparatus described by him as follows:

FIG. 72.



Reduced facsimile of the oldest known (1596) drawing showing details of a water-closet.

"Here are the parts set down with a rate of the prices, that a builder may guess what he hath to pay.

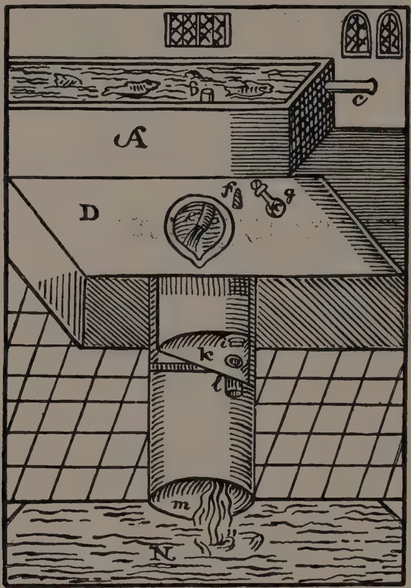
	s	d
"*A* the cistern; stone or brick. Price	6	8
b, d, e the pipe that comes from the cistern, with a stopple to the washer	3	6
c a waste-pipe	1	0
f, g the stem of the great stopple, with a key to it	1	6
h the form of the upper brim of the vessel or stool-pot . . .		
m the stool-pot, of stone	8	0
n the great brass sluice, to which is three inches current to send it down a gallop into the Jax	10	0
i the seat, with a peak devant for elbow-room. The whole charge thirty shillings and eight pence; yet a mason of my masters was offered thirty pounds for the like. Memorandum. The scale is about half an inch to a foot."		

Fig. 73 shows the apparatus set up and during flushing. "Here is the same all put together; that the workman may see if it be well. *A* the cistern. *B* the little washer. *c* the waste-pipe. *D* the seat board. *e* the pipe that comes from the cistern. *f* the screw. *g* the scallop shell, to cover it when it is shut down. *H* the stool pot. *i* the stopple. *k* the current. *l* the sluice. *m, N* the vault into which it falls; always remember that (   ) at noon and at night empty it, and leave it

half a foot deep in fair water. And this being well done, and orderly kept, your worst privy may be as sweet as your best chamber."

We have evidence that even among peoples not classed among the highly civilized, the use of water-closets is by no means of recent date. Thus, Ogilby in his elaborate work on Africa, published in 1670, describing the city of Fez, says, on page 187: "The River Fez which Paulus Jovius calls Rhasalme, passes through the City in two Branches; one runs Southward towards New Fez, and the other West; each of these subdividing into many other clear running Channels through the Streets, serving not onely each private House, but Churches, Inns,

FIG. 73.



Companion to Fig. 72, showing parts put together.

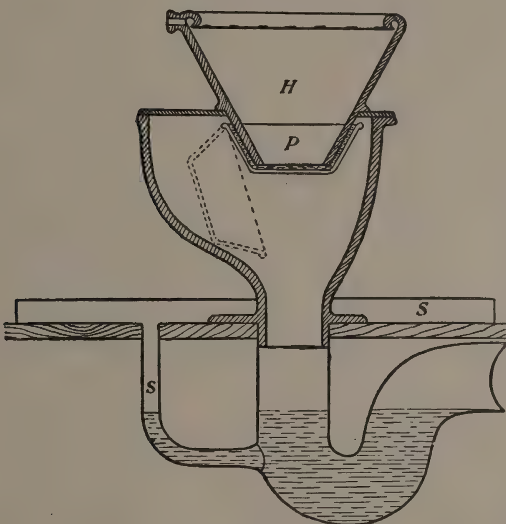
Hospitals, and all other publick Places to their great conveniences. Round about the Mosques are a hundred and fifty Common-Houses of Easement, built Four-square and divided into Single-Stool-Rooms, each furnished with a Cock and a Marble Cistern, which scoureth and keeps all neat and clean, as if these places were intended for some sweeter Employment."

The water-closets of the present day may be divided into two classes: those having movable internal mechanism, and those having none. To the former class belong the plunger, or plug, closet, the pan closet, and a number of others; to the latter belong the hopper closet, the various wash-out closets, the siphon closets, and the siphon jet closets. To attempt to describe all the different forms on the market would be a tedious and useless task, for the patented devices alone run up into the

hundreds. Therefore, in the following pages, only those which may be taken as types of the worst and best will be described. First will be described those of distinctly objectionable construction. These include a number which, while they are no longer introduced in communities having modern plumbing regulations, exist in thousands of houses, into which they were introduced at a time when they were regarded as absolutely perfect.

The Pan Closet.—The principle of this apparatus is shown in Fig. 74, which is a vertical section of the working part of the closet, free from the cabinet work in which it is usually enclosed. It consists of a hopper *H*, provided with a flushing rim and closed at its outlet by means of a hinged pan *P*, which is released by a mechanism which it

FIG. 74.



Pan closet.

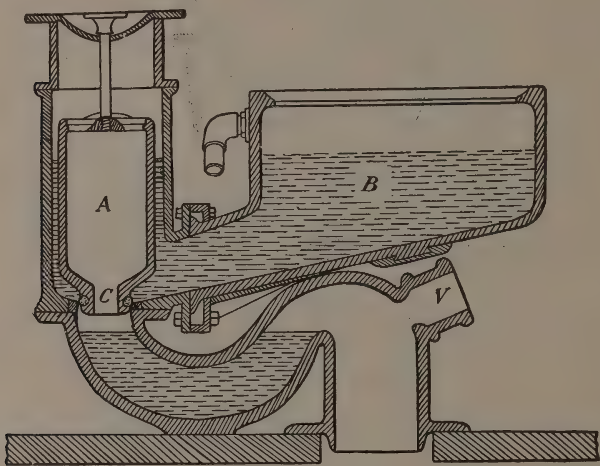
is unnecessary to illustrate or explain. When the pan is in the horizontal position, it is partly filled with water, into which the excreta are discharged, although ordinarily they come in contact first with the surface of the hopper above the water level. The closet is emptied by pulling a knob or handle which releases the pan, which then takes the position shown in the figure by the dotted lines. The contents are thus thrown into the lower chamber, and fall into the trap below. The mechanism which releases the pan also starts a flush of water through the flushing rim over the surface of the hopper. This flush is supposed to scour the interior and to be sufficiently voluminous to drive the excreta over the bend of the trap and forward toward the soil-pipe. When the pan is brought back to its original place, the flush continues until the pan is filled to the same level as before.

As a matter of fact, the flush of these closets is ordinarily little

better than a mere dribble. The front wall of the receiving chamber, against which the excreta are thrown by the pan in its descent, is invariably in a filthy condition, which cannot be improved by any amount of such flushing as the apparatus is capable of giving. The consequence is that each time the pan is dropped, a volume of foul air is displaced upward into the room. The inlet side of the trap is commonly a miniature cesspool, since the flush has so little head that it is unable to drive objects of lighter specific gravity than that of water through the trap. In the illustration, *S* represents what is known as a "safe" to catch all drippings from any source, and from this, the pipe *s* conducts them to the bend of the trap. This whole contrivance, formerly the pride of the plumber's craft, is now generally and justly regarded as an abomination.

The Plunger, or Plug, Closet.—This apparatus, shown in Fig. 75, is far less objectionable than the pan closet. It consists of a receiver *B*,

Fig. 75.



Plunger closet.

in which a large volume of water can be retained when the plunger, or plug, *A*, is in place. When *A* is lifted, the contents of *B* escape downward into the trap, which is vented at *V*. The plunger *A* not only controls the emptying of the receiver, but also acts as a standing overflow, for should the water in the reservoir rise higher than the upper level of the plunger, it will flow over into *A*, and from it through *C* into the trap. This fixture requires a large amount of water in order to obtain a proper flush, for unless the flush is generous, bits of paper and other material may adhere to the edge of the outlet, so that when the plunger is in place the valve is not tight. Naturally, with a loose joint, the contents of the receiver will ooze away and leave it in a dry condition.

These two forms suffice as illustrations of the objectionable class of

closets, and it may be said, in general, that all closets depending upon internal, mechanical, movable parts are objectionable, and all of them are likely to become exceedingly foul.

A properly constructed water-closet should have a flush of water that will wash the whole of the interior surface of the bowl most thoroughly, carry onward all the filth and other material beyond the trap, and leave the bowl filled to the proper height with clean water. It should be cleaned so thoroughly every time it is used, that no filth may remain deposited at any point, and it should be free from disagreeable odor.

Hopper Closet.—The simplest form of non-mechanical closets is known as the *Hopper*, which is shown in Fig. 76. The illustration hardly needs explanation, the device consisting of a hopper connected with a simple S-trap, ventilated in the usual way. Hoppers are known variously as *short* and *long*. The long variety presents no advantage over the short, and is kept much less easily in proper condition. The long hopper has its trap beneath the floor; the short hopper, above it. The short hopper is less likely to become foul, on account of the smaller surface presented, and because the level of the water in the trap is nearer the seat. The hopper should be provided with a generous flush from a flushing rim, for otherwise it is likely to become foul, since, from the shape of the receiver, fouling of its posterior interior surface is inevitable. This is more marked with the long than with the short hopper. Unless the flush is a generous one, it is necessary to pour down an occasional pailful of water, and also to apply the closet brush at least daily.

FIG. 76.

Hopper closet.

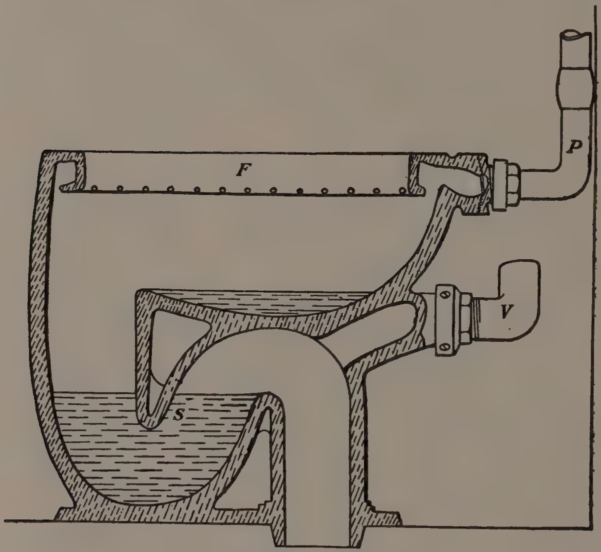
Open Wash-out Closets.—The open wash-out closet is designated variously as front or back or side wash-out, according to the direction which the contents of the bowl take toward the trap. In Fig. 77 is shown a front wash-out in vertical section. The bowl, provided with a flushing rim *F* fed by the supply pipe *P*, holds a pool of water, into which the excreta are projected. The greatest depth of this volume should not exceed 1.75 inches. In use, the contents of the bowl are swept by the water from the flushing rim into the trap *S*, which is ventilated at *V* in the usual manner, and the flow is sufficiently voluminous to force the excreta down and under the partition.

If the volume of water in the bowl is deeper than above stated, it is possible that the flush may sweep beneath any floating excreta, which, in consequence, may be retained. If no pool at all, or only a very much shallower one, be kept, the excreta may adhere to the basin with such tenacity that they are not easily dislodged by a single flush. For

the wash-out closet, it was intended to secure the combined advantages of the hopper and the plunger closets, that is, the advantage of a large surface of water in the bowl in addition to that in the trap, without the intervention of any mechanical contrivance. The objections to the wash-out closets are: (1) that the principal office of the flush is the cleansing of the basin; (2) that after each using, the excreta and paper are likely to remain in the inlet side of the trap until the fixture is used again; and (3) that the surface against which the excreta are thrown during the flushing is likely to become fouled and remain so until cleaned mechanically by means of a brush or other appliance.

Another form of wash-out closet has the basin so constructed as to form a trap. Closets of this class are much like the hopper, but hold

FIG. 77.



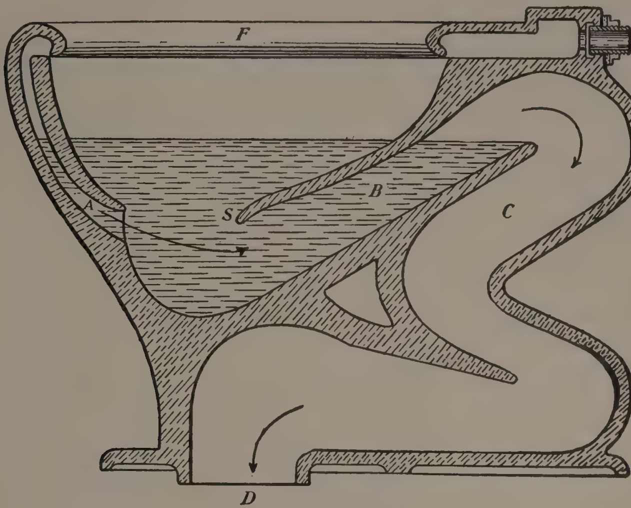
Open wash-out closet.

a much greater depth of water. They are known more commonly as "wash-down" closets. In both the wash-out and the wash-down closets, the lip of the trap should dip not less than 1.5 inches beneath the water level; less than that increases the risk of loss of seal by evaporation, and more requires a larger flush than is ordinarily obtainable to force the excreta, etc., downward and onward.

Siphon Closets.—Another type of wash-down closet is known as the *siphon jet.* In this, the contents of the receiver are drawn out by siphonage, and at the same time are propelled by a jet of water from the front. In Fig. 78, one of these closets is shown. Here the chamber is divided into two sides of a trap by the partition *S.* As the flush is brought into play, a jet of water comes down with some force through *A* and pushes the contents of *B* over into the chamber *C*, and, as the flush continues, the chamber *C* becomes the long leg of

a siphon, so that when the flush ceases to act, the siphon continues to suck out the contents of the receiver until the water level is brought down to the point *S*, when air is admitted and the siphon becomes thereby broken. The after-flush raises the water level again to its original point.

Fig. 78.



Siphon jet closet.

Another form of siphon closet, which acts without the assistance of a jet is known as the *Dececo*. This is a very simple and efficient fixture, invented by the late Colonel George E. Waring, Jr. The receiver is very deep, and maintains several inches of seal. The apparatus is shown in Fig. 79. To assist in charging the siphon, a weir-chamber,

Fig. 79.

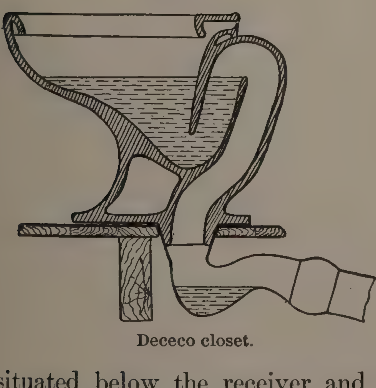
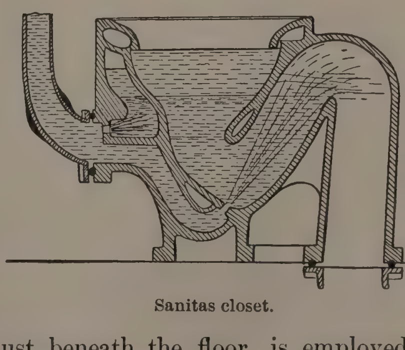

Dececo closet.

Fig. 80.

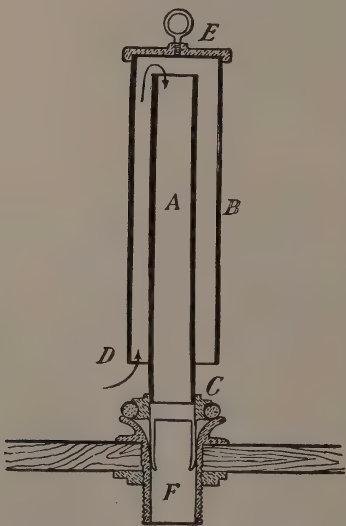

Sanitas closet.

situated below the receiver and just beneath the floor, is employed. When the flush is set in action, the water in the basin overflows and falls into the weir-chamber below. This has a constricted outlet, which is closed very quickly by the descending water, and thereby the

entrance of air from the soil-pipe side is prevented. As the water rushes into the long leg of the siphon, it pushes the contained air onward, the leg is soon filled with water, and the siphon is completed. When the contents of the bowl have been sucked down to the lower border of the partition, the siphon it broken by the admission of air at that point, and the bowl is then refilled by the after-flush.

Still another efficient form of closet is the *Sanitas*, shown in Fig. 80. In this apparatus, invented by Mr. J. Pickering Putnam, the flush is accomplished by the pressure of water in the supply pipe. This pipe enters the bowl below the normal water level and stands permanently full through its entire length up to the cistern. The water is held in the pipe by atmospheric pressure. The upper end of the pipe is closed by the cistern valve, and the lower end by the water beneath the water level of the receiver. The lower portion of the supply pipe is perforated at two different points, through the first of which, water is supplied to the flushing rim, and through the second, a jet is set in action, as in the ordinary siphon jet closet. When the flush is set in operation, the cistern valve is opened, and the water descends and escapes through the two outlets; through the upper, the passage leading to the flushing rim is filled, and through the lower, the water is projected from the bottom of the receiver up into the siphon. The action is very quick and practically without noise. When the cistern valve is again closed, the water ceases to escape through the openings, and that in the flushing rim and passages leading thereto falls back into the bowl and restores the normal level.

Fig. 81.



Valve of siphon tank.

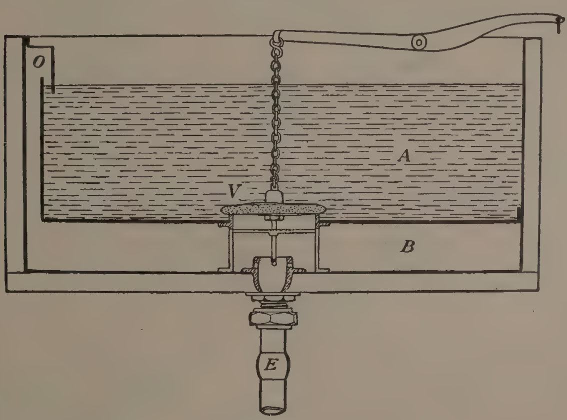
Flushing Apparatus.—The object of a flushing apparatus is the thorough removal of all adhering excreta from the sides of the fixture, and its propulsion through and beyond the trap. The flushing rim is connected with a supply pipe of about 1.25 inches diameter, connected with the cistern. Through this pipe, the water is delivered with a rush, and is spread out by the flushing rim in small jets against the sides of the bowl. With some forms of flushing cisterns, the flush continues as long as the lever which opens the valve is held down or until the cistern is emptied completely.

Another form of flushing cistern is known as the siphon tank, the valve of which is shown in Fig. 81. This consists of a double tube, *A* and *B*, the inner tube *A* being the longer, and the two tubes forming a siphon. The lower end of the long leg of the siphon *A* rests on

a rubber ring at C, and forms the valve. The siphon is started in operation by lifting the valve off its seat by means of a chain fastened to the ring in the cap E. The water rushes downward through the flush pipe F, sucks the air out of A, and fills the siphon with water. The valve is then dropped back, and the discharge continues flowing into the siphon at D, and downward through A, as indicated by the arrows. The discharge continues until the level of the water is brought down to the point D, when, air being sucked in, the siphon is broken. With this apparatus, the flush tank is emptied every time the fixture is used, and the valve needs to be opened only long enough to start the siphon in motion, which object is accomplished in a few seconds.

Still another form of flushing apparatus is shown in Fig. 82. This is employed to furnish a large flush and a small after-flush, by means of which the bowl of the fixture may receive water after the main

FIG. 82.



Flushing tank.

flushing has been accomplished. The tank is divided into two chambers, A and B. The valve V, worked by chain and lever, is 4 inches in diameter. When opened, it discharges water more rapidly than it can flow through the pipe E, and, in consequence, the surplus fills the chamber B. When the valve is closed, the main flush ceases, and a smaller flow continues until the chamber B is emptied. At the point O, is the overflow for the chamber A into B.

A flushing tank should contain not less than 4 gallons, and, except in the case of the Sanitas closet, should be not less than 6 feet above the closet bowl.

Water-closet Connections.—The ordinary method of connecting a modern water-closet with the soil-pipe branch is by means of what is known as a brass floor-plate joint. The soil-pipe branch is fastened by means of solder to a brass flange, which is screwed to the floor. The closet flange is set upon an intervening rubber gasket, and the two are then screwed or bolted together. The common putty joint should not

be used, for although it may not leak water, it is usually pervious to air and odors. In screwing up the porcelain branch, great care should be taken to avoid breakage. Some closets are made in two pieces, the bowl being of porcelain, and the trap of iron or other metal with a porcelain lining. With these, the danger of breakage is reduced to a minimum.

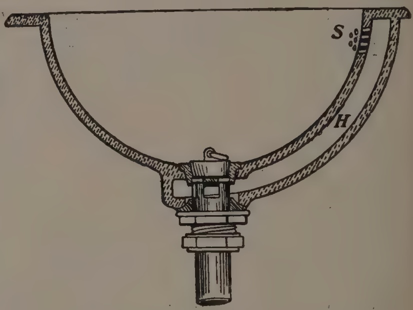
Urinals.—The urinal is a fixture which should not be tolerated in a private house, since, with the best of care, they are almost inevitably offensive and, with ordinary care, are sure to be a decided nuisance. They are necessary only in large buildings, and there they require abundant and frequent flushing and constant care. The waste-pipe is commonly coated on the interior as far as the trap with a deposit derived from the urine, and does not yield it readily to flowing water. The application of washing soda or of solution of ordinary potash is ineffective, but hydrochloric acid in 10 per cent. strength, followed shortly by a generous flush of water, will remove it. Weak sulphuric acid, about 2.5 per cent., is also efficient.

Wash Basins.—Wash basins are made of metal, as copper, enamelled and galvanized iron, and of earthenware and porcelain. Most commonly, they are of glazed earthenware. In shape, they are either circular or oval. The latter form is generally preferred, as it affords more space for free action of the arms than a circular one of the same

Fig. 83.

Wash basin with overflow.

Fig. 84.

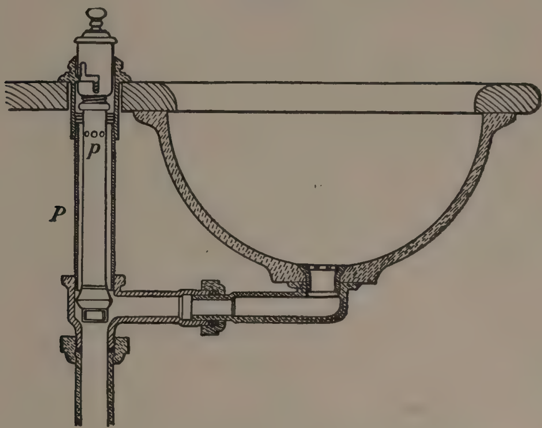


Wash basin with overflow horn discharging beneath plug.

capacity. Some bowls are made with a flushing rim at the top, through which hot and cold water are introduced together on all sides, and thus the entire surface of the bowl is more easily kept clean. In the upper part of the commonest form of basin (see Fig. 83) a number of perforations (S) communicate with the overflow horn (H) connected with the waste-pipe. Ordinarly, these outlet holes are unable to deliver water as rapidly as it enters through a faucet with moderate head, and consequently too much dependence should not be placed on them in the prevention of overfilling of the basin. In some bowls, the entire overflow horn is an integral part of the fixture, opening just beneath the plug, as shown in Fig. 84. Where the horn does not so extend, its junction with the waste-pipe is not infrequently wrongly made; sometimes, it is connected below the trap; sometimes, at the crown of the trap, into or near the vent pipe. The

overflow horn, especially with long use of the fixture, is very likely to become foul, on account of the soap and filth which become deposited

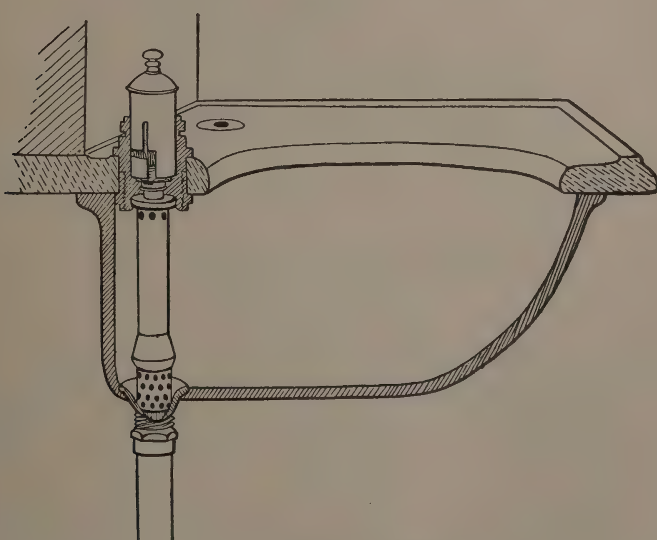
FIG. 85.



Wash basin with standpipe plug and overflow.

along its inner surface. In fact, the odor which is ascribed commonly to "sewer gas" comes from the horn and from the waste-pipe between the bowl of the trap. Another source of odor of much less importance

FIG. 86.



Improved standpipe overflow.

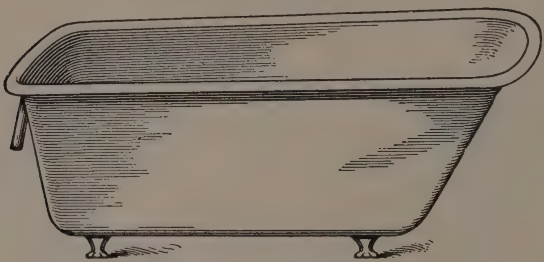
is the chain attached to the plug. This gradually collects within its links the same kind of deposit, which is removed completely only with

some difficulty and much scrubbing with a brush. On account of the fouling of the chain and the inconvenience of having it in the way of the hands, some forms of basins are equipped with a standpipe, which acts as plug and overflow at the same time. In Fig. 85 such an arrangement is shown; the bowl presents no irregularities of surface, not even a plug. The standpipe *p*, enclosed in the pipe *P*, acts as a valve when it is dropped into place, and the surplus water, rising between *P* and *p*, escapes through the holes in the upper extremity of *p*. The device is lifted by a knob, and is kept off the seat by means of a bayonet catch. In the illustration, the plug is off the seat.

The principal objection to this form of waste-valve is that the outlet is situated at a considerable distance from the outlet of the bowl, and the entire surface between these two points is certain to become foul. Furthermore, small bits of lint and hair are likely to be deposited near the seat and cause it to leak so rapidly that the bowl cannot hold water for any length of time. A better form is shown in Fig. 86. Here the standpipe overflow has its seat directly in the outlet of the basin, and may easily be got at and cleaned.

Bathtubs.—Bathtubs are made of various materials in a number of forms. The finest grade of tubs are made of porcelain or of fine earthenware with a heavy enamel of porcelain. They are made in various shapes and very commonly are decorated somewhat ornately. They are very heavy and quite expensive. The plainest varieties have most commonly the shape shown in Fig. 87. They are usually set

FIG. 87.



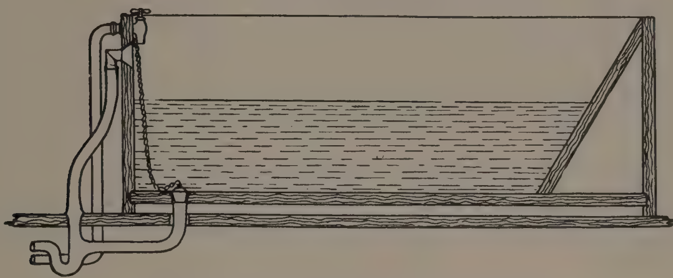
Porcelain or iron bathtub.

upon slabs of marble. Tubs of iron with a lining of porcelain enamel also are made in this form. These are open to the objection that the enamel is chipped off very easily. Within recent years, a cheap form of tub in this shape, made of ordinary tin plate, has been introduced. In spite of the iron frame with which it is surrounded, it is constructed very flimsily.

The commonest form of bathtub used in this country is made of tinned and planished copper, weighing from 10 to 24 ounces to the square foot. In Fig. 88, this form of tub is shown in vertical section. Inasmuch as the copper is to all intents and purposes the lining of a box, it is necessary, for the sake of appearances, to have an outside

casing of cabinet work. The ordinary tub is provided with a waste plug, chain, and overflow, as shown in the figure. Not uncommonly, the chain and plug are supplanted by an ordinary pipe of the desired length,

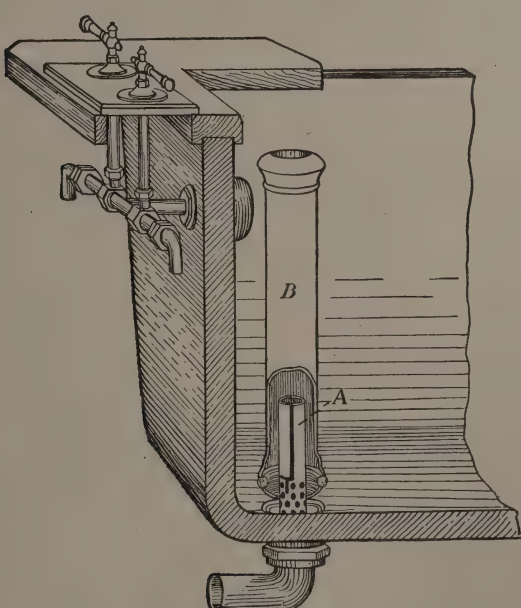
FIG. 88.



Vertical section of commonest form of bathtub.

which fits into the outlet of the tub, and thus acts both as plug and overflow. In some of the tubs of more elaborate construction, a standing overflow and waste-pipe, shown in Fig. 89, is used. In this, the

FIG. 89.



Standing overflow and waste-pipe.

overflow passes over and into the pipe B and escapes through the bottom. When the tub is to be emptied, the tube is lifted, and thereby the perforations at the bottom of the inner tube A are exposed. On

the whole, this form is in no way superior to the ordinary standing overflow, but possesses certain disadvantages which do not apply to that device, which can be removed completely from the outlet each time the tub is emptied.

Other forms of baths, including the sitz-bath, foot-bath, shower-bath, douche, and needle-bath, and bidets are found ordinarily only in the very elaborately fitted bath-rooms of the very wealthy. As plumbing appliances pure and simple, they possess no special hygienic interest, the matter of waste-pipes, trapping, etc., differing in no essential respects from what has been described in connection with other fixtures. The shower-bath, which consists mainly of a large sprinkler from which water is delivered downward in fine streams, is very commonly set above the ordinary bathtub, with a screen of wood or curtain of rubber cloth or other suitable material to prevent splashing the floor. Smaller arrangements, consisting of a sprinkler, such as is attached to the nozzle of a watering-pot and a rubber tube to connect with the faucet of the bathtub, are very commonly used. If desired, the rubber tube may be attached to a mixing pipe, which in its turn is attached to both cold and hot water faucets, and thus the temperature of the shower may be regulated.

Sinks.—Under sinks are included pantry sinks, kitchen sinks, and slop sinks. These are made of various metals, including cast-iron, enamelled iron, steel, and copper, and of soapstone, slate, earthenware, and porcelain.

Cast iron is easily kept clean with ordinary care, but on account of danger of the breaking of dishes and other articles which are washed or otherwise handled in them, a grating of wood not uncommonly is laid on the bottom. This easily becomes foul, particularly if it is allowed to stand in the wet sink when not in actual use. All such gratings should be kept scrupulously clean, and when not actually needed in the sink, should be hung up in the air.

Enamelled iron is much more desirable than plain iron, and presents a much better appearance. Unfortunately, however, the enamel is very easily cracked and detached.

Steel sinks are not so durable as ordinary cast iron, but they are light and cheap. They are very commonly enamelled, and then they are necessarily open to the objection above mentioned.

Tinned and planished copper is much used for pantry sinks, which are made commonly with rounded, but, better, with perfectly flat bottoms. The copper should have a weight of not less than 18 to 24 ounces per square foot.

In some quarters, soapstone is the favorite material for kitchen sinks. Ordinarily, it is quite durable, particularly if it has been subjected to a preliminary oiling, but some specimens show a tendency to disintegrate very rapidly, and to become so pitted as to present a honeycombed appearance.

Earthenware sinks are thick and heavy, and present no advantages over soapstone.

Porcelain is expensive, and, if thin, is easily broken. It is not extensively used in ordinary sinks.

All sinks should be provided with a not too fine strainer over the outlet. Kitchen and pantry sinks are connected best with a grease trap. The common practice of constructing cupboards or closets beneath sinks should be discouraged, since these spaces are commonly maintained as clutter-holes in which to store unwashed pots, kettles, and other utensils, which, in unclean condition, would not be tolerated in positions where they are open to inspection.

House-maids' sinks, commonly known as **slop sinks,** are located generally in small, dark, unventilated closets in the upper story. This form of fixture is made rather deeper than an ordinary sink, and is sometimes shaped like a hopper. They are made best with a flushing rim, which will assist in keeping the entire surface clean and free from odor. On account of the nature of the refuse poured into these receptacles, and because of the great probability of the occurrence of splashing when vessels are emptied, these sinks are often extremely foul, and the closets in which they are placed are then always necessarily offensive. The greatest care is necessary to insure cleanliness.

Laundry Tubs.—Laundry tubs are made of practically the same materials as sinks. The cheapest kind is made of stout planking with well-fitting joints drawn tight by iron bolts. This form is not very durable, since the alternate drying and wetting soon ruins the joints and causes the wood to decay. Those made of porcelain and earthenware are heavy and expensive, but are very durable and readily kept clean. The soapstone tub is regarded generally as the most satisfactory, but it should be made of material of the best quality, since otherwise it is liable to chip and crack off from constant contact with hot water. All enamelled tubs are likely to lose their enamel, which is separated easily from the metal and chipped off.

House Service Tanks.—With most plumbing systems, it is essential that, in the upper part of the building, above the highest fixture, there shall be a service tank to feed the hot-water boiler and the various flushing cisterns connected with water-closets and other fixtures. These tanks are commonly placed in positions where access to them is not easy, and, in consequence, they are, as a rule, examined very infrequently. No matter how carefully they are covered and regardless of the kind of water that enters them for storage, they accumulate more or less dust, dirt, organic matter, and other sediment. All this adheres to and accumulates on the bottom, forms a slimy coat upon the sides, and there remains until removed by some external force. It is hardly necessary to say that this condition should not be permitted. The tank should be inspected periodically and thoroughly cleaned. Fortunately, it is neither necessary nor customary in ordinary dwellings to use water from the service tank either for drinking or for cooking, since the cold-water service pipes connect directly with the street main, and are tapped at intervals with faucets and terminate at the tank, where their delivery is regulated by means of ball-cocks. Inasmuch as the water from the

tank is not used for drinking and cooking, excepting in houses not connected with the public supply, but served from a tank filled periodically by pumping, it makes no very great difference from a hygienic standpoint of what material the tank is built. A very good tank is made of riveted iron plates lined with cement of proper quality. Wooden tanks are much used, and give satisfaction if they are kept full and clean. The tank which, on the whole, is most satisfactory is constructed of wood, with the sides secured to the ends by long bolts, and lined with tinned copper of good weight. Lead forms a poor lining, for it is corroded easily by water. Galvanized iron and sheet zinc also make poor lining material. In large office buildings in which all the fixtures, including those from which water for drinking is obtained, are supplied from a main tank in the upper story, it is advisable that the lining of the tank should be of tinned copper, and under no circumstances should it be of lead.

Service Pipes.—The method of installing the water service is of slight interest to the hygienist and requires no discussion, the nature of the pipes having been considered in another chapter; but there is one minor trouble connected with them which may be a cause of great annoyance, especially to persons of nervous or irritable nature. This trouble is commonly known as *water-hammer*, and is something more than an annoyance, since its occurrence has a weakening effect on the entire pipe system. This is the quivering and rattling that occur from end to end when the current of water within them is checked suddenly by the quick closure of a cock or valve. In order to prevent this, it is necessary to make some provision for a cushion, particularly where the water pressure is very great. This not infrequently runs as high as a hundred pounds to the square inch, and even higher. To cushion the blow, an air chamber, commonly made by turning the pipe upward for a foot or two above the cock, is used. This extension will at the outset contain a volume of air, which, on being compressed by the force of the water, makes an elastic cushion. Sometimes, however, the air originally contained becomes gradually absorbed by the water which is driven into the chamber, and thus it becomes replaced by water and the cushion is destroyed. In such an event, it is well to shut off the water and empty the pipes so that air may again fill the chamber. Another form of air chamber recommended is made by extending the pipe with a piece of larger diameter, covered at the top with a tightly fitting screw cap. Within this extension, may be placed two or more rubber balls, upon which the force of the blow of the water-hammer may be expended.

Water-hammer of a most annoying and persistent kind is occasioned often by the too easy movement of a light ball-cock controlling a current of high pressure in a small tank. For example, the water in the tank becomes lowered through the use of some fixture below, the ball, floating on the surface, opens the valve of the cock, and water is admitted to take the place of that which has been drawn off. The water, entering with much force, sets the whole contents in motion.

The ball is thrown up and shuts off the water with great suddenness and falls again; another jet of water is thrown in, and thus, with alternate quick jets and movement of the ball, the hammering continues, until finally the level of the water has been restored to its original point.

Testing Plumbing.—Tightness of joints throughout a system of plumbing may be determined in several ways. For testing the joints of soil-pipes and main drains, a most important and searching test is that known as the water-pressure test. This is applied before any fixtures have been joined to the wastes and soil-pipe. All outlets are closed with appropriate plugs, made for the purpose and kept in place by means of bolts, and then the entire pipe with its branches is filled with water. Should there be leaks in any part of the system, the fact will be made manifest by the sinking of the water, and the points of escape may easily be found on inspection.

The other methods applicable to the entire system include the smoke test and the peppermint test. In the smoke test, the system is filled with smoke by means of a device known as an asphyxiator. If leaks exist, the fact will be made evident in two ways: first, to the sense of smell; second, to the sense of sight. Besides the asphyxiator, a number of other devices, including the smoke rocket, have been invented. The common method of testing plumbing in this country is known as the peppermint test. For this test, the presence of two persons is necessary; one to apply the peppermint, and the other to detect its presence in the air of the building. About two ounces of oil of peppermint are used for each stack of soil-pipes. This very pungent oil should be carried through the house in very tightly corked vials, in order that no odor shall be given off in transit. The vent openings are closed first with plugs, and the oil of peppermint is then poured into the soil-pipe, and is followed by a quart or two of hot water, to assist its volatilization. The outlet is then closed securely. On account of the clinging quality of the odor, the person who empties the peppermint should remain on the roof, with the scuttle closed, until thorough inspection of the premises has been made. The vapor of the oil permeates all parts of the soil-pipe and its connections, and in case of defective seal or any other imperfection in the system, it escapes and makes its presence known in the rooms through its effect on the sense of smell. During the examination, it is important that no water-closet be pulled and that no bowl, bath, or sink be used, since thereby the whole of the peppermint may be driven out of the system into the sewer.

CHAPTER VI.

DISPOSAL OF SEWAGE.

THE composition of sewage varies according to the character of the community by which it is produced. To the lay mind, the word conveys the idea of a mixture of urine and fæces, paper and burnt matches, with waste from baths, wash-stands, laundries, and kitchen-sinks; this is ordinary domestic sewage, and may be taken as the type of sewage of districts that are purely residential. But the sewage of a large community in which all manner of manufacturing is carried on is necessarily of a most complex character, containing, as it does, in addition to domestic waste, that which is inseparably connected with the various industries. Moreover, it is ever changing with increase and diminution and changes of all kinds in manufacturing activity.

Establishments like paper mills, tanneries, dye-houses, and woollen-mills produce enormous amounts of sewage. In fact, a single one is quite capable of producing as much as that of a fairly large town, and such manufacturing sewage often contains much more organic and other matters than domestic sewage, which, in purely residential districts, is of fairly constant composition, and, where the water supply is abundant, contains but a small fraction of 1 per cent. of organic matter. But it is in this very small percentage that the capacity for producing mischief resides, for the most important constituents of sewage are those which in any way may be the cause, direct or indirect, of injurious effects on health—that is, organic matters connected with infective diseases, and hence mostly to be found in ordinary domestic wastes. Industrial sewage is of secondary, but, nevertheless, in many ways, of great, importance, for its nature may be such as to make separate treatment necessary, because of its action on the life of fish in rivers, and on that of the organisms which bring about purification by methods to be described. It may contain all manner of chemicals, dyestuffs, and other matters, and be repugnant to sight and smell.

The importance of removal and disposal of filth needs no elucidation. Removal should be speedy and final disposal so thorough as to remove completely the possibility of injuriously affecting health. It should not be stored on the premises in cesspools, as is so commonly the practice both in small and in many large and densely populated places, whether these be of the leaching sort which drain their contents constantly into the subsoil, or the far less objectionable, but, nevertheless, objectionable, tight pits with cemented sides and bottoms, in which the contents are always in a condition of putrefaction. The use of this sort necessitates more or less frequent emptying, which, unless done by

the "odorless excavation" suction apparatus (and sometimes even then), gives rise to intolerable stench, not confined to the immediate neighborhood, but disseminated over a wide area.

As will be shown later, fresh sewage may be disposed of so as to lose its character completely, without undergoing the processes which we designate collectively as putrefaction. Its organic constituents are seized upon by micro-organisms which work in the presence of air, and they are converted to inoffensive harmless products which possess the additional property of being invaluable plant foods, such, for instance, as the nitrates of potassium and sodium. But when filth is conserved in pits so that only its upper surface is exposed to the oxygen of the air, its decomposition is effected by a variety of organisms of a different class, which work without air and produce entirely different chemical compounds, including hydrogen sulphide and other noisome bodies. Although sewage which has undergone putrefactive changes may yet be acted upon by the beneficent nitrifying organisms, it is best to get rid of it before such changes become advanced.

Before proceeding to the consideration of the various methods of disposal of excreta and other wastes, it may be well to look into the matter from an economic standpoint. It is very commonly the case that the question of methods to be adopted is influenced largely by the hope of gain, for it is axiomatic in the minds of many that municipal sewage is possessed of such immense manurial value that its disposal without previous treatment for the purpose of reclaiming its valuable constituents is sinful wastefulness. This idea has doubtless never been more forcibly expressed than by Victor Hugo, in the following passage:[1]

"Paris casts twenty-five millions of francs annually into the sea; and we assert this without any metaphor. How so, and in what way? By day and night. For what object? For no object. With what thought? Without thinking. With what object? None. By means of what organs? Its intestines. What are its intestines? Its sewers. Twenty-five millions are the most moderate of the approximative amounts given by the estimates of modern science. Science, after groping for a long time, knows now that the most fertilizing and effective of manures is human manure. The Chinese, let us say it to our shame, knew this before we did; not a Chinese peasant—it is Eckeberg who states the fact—who goes to the city but brings at either end of his bamboo a bucket full of what we call filth. Thanks to the human manure, the soil in China is still as youthful as in the days of Abraham, and Chinese wheat yields just one hundred and twenty fold the sowing. There is no guano comparable in fertility to the detritus of a capital, and a large city is the strongest of stercoraries. To employ the town in manuring the plain would be certain success; for if gold be dung, on the other hand, our dung is gold.

"What is done with this golden dung? It is swept into the gulf. We send at a great expense fleets of ships to collect at the southern

[1] Les Miserables, part 5, book 2.

pole the guano of petrels and penguins, and cast into the sea the incalculable element of wealth which we have under our hand. All the human and animal manure which the world loses, if returned to land, instead of being thrown into the sea, would suffice to nourish the world. Do you know what those piles of ordure are, collected at the corners of streets, those carts of mud carried off at night from the streets, the frightful barrels of the night-man, and the fetid streams of subterranean mud which the pavement conceals from you? All this is a flowering field, it is green grass, it is mint and thyme and sage, it is game, it is cattle, it is the satisfied lowing of heavy kine at night, it is perfumed hay, it is gilded wheat, it is bread on your table, it is warm blood in your veins, it is health, it is joy, it is life.

"So desires that mysterious creation, which is transformation of earth and transfiguration in heaven; restore this to the great crucible, and your abundance will issue from it, for the nutrition of the plains produces the nourishment of men. You are at liberty to lose this wealth and consider me ridiculous into the bargain; it would be the masterpiece of your ignorance. Statistics have calculated that France alone pours every year into the Atlantic, a sum of half a milliard. Note this; with these five hundred millions, one quarter of the expenses of the budget would be paid."

Concerning the fertilizing value of human excreta, there can be no doubt; but when these are diluted to such an extent that their organic constituents amount to less than a thousandth part of the whole, it naturally follows that to reclaim them in concentrated form involves an expense which may be far in excess of their value. A substance which, in hand, is of intrinsic value, may be so situated that its acquisition by ordinary known means cannot be justified because of the attendant pecuniary risk, and then, and until other better means are devised, it is practically worthless. For example, many districts abound in rocks containing silver, gold, and other metals, but in such small amounts that they cannot be worked with profit; therefore, so far as increasing material wealth is concerned, these ores might as well be at the bottom of the sea. But in the case of sewage, the difficulty is increased still farther by the fact that the manurial product is not usable on the spot, but must undergo transportation, which is costly in proportion to the distance.

A fair estimate of the value of the manurial matters contained in a ton of crude sewage of average composition places it at somewhat less than four cents, an amount so small as to appear worse than ridiculous when we consider that it is diluted by a volume of water equal to about six barrels. The value of the sewage of cities with a very abundant water supply is even less than this. Thus, that of Boston has been estimated by the Massachusetts State Board of Health to be about one cent per ton, and that of New York is said to be even smaller. To separate this small amount, the employment of some chemical is necessary. The resulting compound, known as sludge, has a certain value in agricultural operations, but that that value is not such as to warrant

the cost of handling and transportation, is most evident when it is stated that as a rule it finds no market at any price. In London, for instance, thousands of tons of wet sludge are produced every day, more than 2,000,000 yearly, and anybody who wants it can have it free of charge; but nobody cares enough for it to transport it, and hence it has to be carried far out to sea to Barrow Deep, fifty miles away, and dumped.

In considering sewage disposal, it should be borne in mind, therefore, that it is a positive public necessity as much as police and fire patrol, that it costs money, and that it cannot be a source of income over expenditure. No community expects a pecuniary return on an investment for steam fire-engines and hose carriages, or for revolvers and police stations: such are needed for the protection of life and property. So, too, a system of sewerage and sewage disposal is necessary for the protection of health, and is not to be treated as though primarily intended as a source of public revenue, although, of course, any return which may be possible, either from sale of sludge or crude sewage, may be regarded as a welcome diminution in the cost of maintenance.

METHODS OF SEWAGE DISPOSAL.

The methods of disposal of excreta and sewage include:

1. Discharge into the sea or other bodies of water.
2. The "dry method," or pail system.
3. Chemical treatment.
4. Irrigation, or "sewage farming."
5. Filtration.
6. Other biological systems.

1. **Discharge into the Sea.**—In communities on and near the coast, it is a comparatively easy matter to get rid of sewage by discharging it into the ocean and having it carried away by the outgoing tide. If it be discharged in a fresh condition, it becomes so enormously diluted in a very short time that only under exceptional circumstances can it ever be a nuisance in any way. This, of course, presupposes a reasonable rise and fall of the tide, and does not contemplate such slight differences as a foot or so. With slow movement, less than one and a half miles per hour, deposits are more than likely to be formed, and nuisance thus caused must of necessity increase with time, and especially with increase of sewage due to growing population. Thus it happens that, even on the seaboard, it may be necessary to purify sewage before discharging it, and the problem of successful and economical purification may be one of the most difficult and important in the whole range of sanitary science.

In inland communities situated on rivers of considerable size, delivery at a point below the outskirts is the easiest method of sewage disposal; but other communities farther down may properly object on more than one ground to such action, for the sewage itself may be a nuisance, and

the river may be the source of the public water supply. Here, again, and where the flow is sluggish and the volume small, treatment before discharge is necessary. Where the water into which the sewage is delivered is to be used below for the public drinking supply, the process of purification should be such as to give the most perfect results possible; that is, should give an effluent which will not affect the quality of the water injuriously.

In both rivers and harbors, in order to prevent nuisance from untreated sewage, the current should be sufficiently voluminous and strong to afford large dilution and prevent deposition.

2. **The Pail System.**—This is limited in its application to the disposal of excreta in pails containing dry earth, peat powder, or other material, and although it is in operation in several places of considerable size in England and on the Continent, it is better adapted to the needs of isolated houses and small villages. It was the natural outgrowth of the very extensive adoption of the earth-closet, a device invented by the Rev. Henry Moule, in which the solid excreta are discharged into a receptacle of suitable size and covered after each addition with dry earth, peat powder, or ashes. As often as necessary, the pails are collected and emptied, and their contents are removed to a distance, treated or not with chemicals, according to circumstances, and buried or used as manure. From the fact that the collection is made at night, arose the common term *night-soil*, and later, from this one, another to designate an important part of house plumbing, the soil-pipe.

It is a primitive sort of system, but it has points in its favor as well as against. It is not expensive, there is no pollution of streams, and the manurial value of fæces is not wasted. But it requires the collection, drying, and storage of a large amount of earth, or other material, not always easy to obtain; the emptying of the pails is necessarily accompanied by the escape of more or less odor; it may possibly give rise to a nuisance at or near the place of final disposal; and additional provision must be made for the removal of liquid refuse.

The materials used in the pails are chiefly dry earth and peat, both of which substances are very absorbent. The earth is ordinarily either simply dried or thoroughly baked, but drying is preferable to baking, because the influence of the saprophytic bacteria of the soil is not destroyed. The late Colonel Waring demonstrated most convincingly the very great power of air-dried soil to dispose of the organic constituents of fæcal matter so nearly completely that but an insignificant amount remains. He kept two tons of dry earth for a long time, using it repeatedly in earth-closets and storing it after each period of use in a dry well-ventilated cellar. It was estimated that by the time it had been used ten times, no less than 230 pounds of nitrogen had been added to it, but analysis showed that but 8 pounds remained, the rest having been restored in gaseous form to the atmosphere. The same fact has been observed by Professor Vollcker, who found that earth

after being dried and used three times contained practically no more nitrogen than it did originally.

Peat has not only remarkable power of absorption, but also very marked bactericidal properties. It will absorb and retain from nine to eighteen times its weight of water, it acts as a deodorant in the same manner as charcoal, and it retains ammonia in apparently unchanged condition. The resulting manure is found to decompose rapidly, and to be especially suited to sandy and light loamy soil. Experiment has shown that neither the typhoid nor cholera organisms retain their vitality in contact with peat longer than a very few hours, and the same is true of many other varieties of bacteria.

Sawdust also is recommended for use in earth-closets, and as an absorbent for urinals where there is no water supply. Experiments conducted by Dr. G. V. Poore[1] with various materials proved its value for the latter purpose and yielded interesting results. A flannel bag, two and a half feet long and a foot broad at the bottom, containing 6 pounds of dry sawdust, received in the course of two months 39 pounds of urine; after about a year, 45 pounds more were added during a period of three months. Notwithstanding that the bag had become so rotten as hardly to hold together, the contents were not in the least offensive, and had never given off any offensive odor. Of the 84 pounds of urine added, only 6 pounds had filtered through, while the rest had evaporated or had been retained. The filtrate was dark brown in color, thick, and of high specific gravity, but never offensive; nor had it shown, after lying about for months, any tendency to putrefy or become offensive. Filtration through earth, old stucco, and peat moss gave identical results. With fresh earth, fresh stucco, and fresh ashes, the filtrate was almost colorless and odorless, but the power of ashes to give this result is short-lived.

The pail system, whatever may be said in its favor, has had its day in large communities, and where it still obtains, it is being superseded gradually by systems more suitable and satisfactory.

3. **Chemical Treatment.**—Sewage disposal by chemical treatment has for its object the separation of the suspended matters and the precipitation and consequent separation of the putrescible matters in solution. The larger masses of the suspended substances may, of course, be removed by being entangled in the coagulum produced from the soluble matters by the addition of chemical precipitants. The effluent should be clear, and should contain a minimum of organic matter capable of undergoing putrefaction. Whatever the precipitant used, the process requires constant and careful supervision, in order to achieve the best results and to keep the expenditure down to as low a figure as is consistent with efficiency. The screened sewage, deprived of its coarser matters, is treated and thoroughly mixed with the chemicals in large tanks, and is then passed into other tanks, where the precipitate is allowed to separate by subsidence. The sludge is removed and then disposed of in its natural state or after treatment in hydraulic

[1] British Medical Journal, Aug. 31, 1895.

presses for removal of the water. The sewage should be treated in as fresh condition as possible and before putrefactive processes have begun, since when the latter have got well under way, the results are never satisfactory.

The substances most used as precipitants are alum, lime, and ferrous sulphate, but which of these and others is the best suited for the work, is a question concerning which there is no general agreement. Alum and other soluble salts of aluminum have moderate disinfectant properties, are not poisonous in the general sense of the word, and when used in excess impart no color to the effluent. In the presence of lime or ammonia, they yield a very bulky gelatinous precipitate, which entangles the suspended matters and bacteria present, and carries them down, leaving a clear supernatant fluid, which is without color or odor and practically sterile.

With excess of alum, the effluent is acid in reaction, and is thus capable of injuring aquatic life; but it does not form unsightly compounds with sulphur as do iron and other substances which form black sulphides. Lime in the form of milk of lime is used extensively both alone and in connection with ferrous sulphate or alum. When used alone, it gives a much more bulky sludge, which has but slight value as a fertilizer. The amount necessary for treatment of a million gallons of sewage is generally stated at one ton, but may be much less. At the precipitation works at Worcester, Mass., for instance, during the year ended Nov. 30, 1895, the average daily amount of sewage treated was 16,000,000 gallons, and the average amount of lime used per million gallons was but a trifle over 1,200 pounds, while the sewage of Lawrence, Mass., was found in the experiments conducted by the State Board of Health,[1] to require 1,800 pounds for the same amount. As a matter of fact, the amount necessary depends upon the character of the sewage, that is, upon the amount of carbon dioxide in it, for it is this which acts upon the lime to cause a precipitate to be formed. Hence it may be said that the amount necessary is that which will exactly neutralize the contained carbon dioxide.

Ferrous sulphate is very rarely employed alone, but generally with lime, the two being used in such amounts that no great excess of either is left in the effluent; and these amounts can only be determined by actual experiment with the sewage to be treated. On this account, precipitation by ferrous sulphate is likely to be somewhat complicated, but when it is carried out properly, it appears to give very good results. The experiments conducted by the State Board of Health at the station at Lawrence led to the conclusiou that sulphate of iron alone acts best among chemical precipitants. According to Mr. W. J. Dibdin,[2] however, who, as is well known, has made extensive experiments on this subject, the combination with lime constitutes the most economical and most efficient agent. An excess of iron in the effluent may lead later

[1] Report on Purification of Sewage and Water, 1890.
[2] Journal of State Medicine, January, 1895.

to an unsightly deposit of ferrous sulphide along the banks of the stream into which it is eventually discharged.

Certain other chemical processes have been exploited in this country and elsewhere, but none of them appears likely to be adopted extensively. Among them may be mentioned the "Amines" process, in which the sewage is treated with lime and amines, chiefly trimethylamine, in the form of herring-brine. While this process gives satisfactory results, it has certain drawbacks, among which are the difficulty of securing a sufficient supply of the brine, the offensive odor of the same, deterioration on storage, and possible influence on fish life. Another, sometimes known as the "Woolf," and sometimes as the "Hermite," process, depends upon the action of chlorine compounds produced by electrolysis of salt in sea-water or in the sewage itself. The organic matters are attacked and somewhat diminished in amount, but the principal influence is exerted in the direction of sterilization. The precipitating agent is ferrous hydrate, formed by the action of the electric current on iron plates in the tanks. In the so-called A. B. C. process (alum, blood, and clay), a mixture of clay and charcoal is first added to the sewage, and next a solution of alum and sulphate of magnesium. It is an expensive and troublesome process, and yields a large amount of sludge. Blood was employed originally, but was found to be unnecessary.

In all processes of chemical treatment, a more or less complete temporary sterilization is effected, and this of itself is often a very serious objection, since, although the effluent when discharged may be sterile, this condition is not lasting, and the organic matter still present will certainly, sooner or later, decompose, and, perhaps, become a serious nuisance. The objection to sterilization of sewage does not extend, of course, to the pathogenic bacteria of infected fæces and urine, which should be destroyed before entrance to the main body of sewage, but wholly to the saprophytic organisms, which eventually destroy the organic matters and convert them to simple, harmless compounds.

There is always more or less organic matter in the effluent, however clear this may be, and, being putrescible, it is certain to undergo change. This has been demonstrated wherever chemical treatment has been adopted, and it is admitted generally that the effluent cannot be admitted to water courses without injury to the quality of the water, both so far as fish life and wholesomeness for drinking are concerned, unless it is first further treated by some biological process, and thereby made clean and harmless. In the words of Professor L. P. Kinnicutt,[1] who has made an exhaustive study of chemical purification at Worcester, Mass., and elsewhere in America and in Europe, "We believe we have proved in America . . . that by chemical precipitation alone, even with the greatest care, and at an excessively high cost, a filtrate cannot be obtained sufficiently pure to turn into a water course unless the minimum dry weather flow of that water course is at

[1] Journal of the Sanitary Institute, Jan., 1900, p. 662.

least ten times, and, better, fifteen times the average flow of the sewage."

Action of Sewage Effluents on Fish Life.—It may be stated broadly that "purified" sewage, when discharged into a water course, will cause more harm to fish than will ordinary crude sewage, for while all chemical precipitants will either cause the water to act as a poison or withdraw its dissolved oxygen so that it will not sustain life, the elements of crude sewage may be taken up greedily by the fish as valuable food material. Much depends, of course, upon the nature of the precipitant (some of them being more poisonous than others), and also upon its amount; but even when extensively diluted, its action is distinctly harmful. Lime is supposed to act by being precipitated in the gills as carbonate, thus diminishing the respiratory area. Chlorine, in a free state or as chlorinated lime or soda, exerts, even in extremely dilute condition, as less than 1 part in 100,000 of water, a very fatal influence. Iron salts act not only as poisons, but the ferrous forms take up the dissolved oxygen and become ferric; then these become reduced and again absorb it, and continue in this way to rob the water of its power to sustain the respiratory function. But, on the other hand, while fresh sewage of ordinary composition is sought for by many species of fish as a desirable food, putrefying sewage will either act injuriously on fish or make the water so repugnant to them as to drive them away.

4. **Sewage Irrigation.**—In the "broad irrigation" or "sewage farming" system, sewage is utilized in the growing of crops which take up and dispose of much of the water and dissolved solids, while, at the same time, oxidation processes in the interstices of the soil destroy the bacteria and convert the remaining organic matter to simple, harmless products. For the disposal of large volumes by this method, very large sewage farms are required. The necessary area will depend upon the nature of the soil, its permeability and water capacity, and upon the amount of annual rainfall.

This method has been adopted very extensively in England, where there are hundreds of sewage farms, and in Germany, France, India, America, and elsewhere; and everywhere it has been found that no hard and fast rules as to area per thousand of population can be followed. In England, the idea obtains very generally that every hundred of population will require one acre of sewage farm, but this, it should be remarked, while it may apply in England, which is a rainy country, and one where domestic sewage is likely to amount to many more gallons per capita than on the Continent, owing to the more general habit of daily bathing, is much in excess of actual need where the soil is more suitable for the purpose, where the rainfall is less in amount, and where domestic sewage per capita is produced in smaller quantities. According to Waring, each acre of a well-regulated plant will, under ordinary conditions, absorb and purify the sewage of 250 to 500 persons, and if the soil be of porous fine sand and the question of crops be put in the background, that of 1,000 to 1,500. As the population

grows, the plant must be enlarged, and hence it is necessary to hold land in reserve to meet future demands.

Of the very first importance is the selection of a suitable tract of land for the establishment of the plant. This, of course, is not always possible, for sometimes no land is available, and, again, such as is at hand may be unsuited to the purpose. It should be neither too permeable nor too close. If too coarse, it will permit the passage of the sewage so rapidly that no purification, or at most imperfect purification, will occur, and the effluent will be unfit to be discharged from the underdrains into a water course; if too close, as will be the case with a very dense clay, the imbibition of water will be so slow that it will fall far below the amount of loss by evaporation. The very best soil for the purpose is one of sandy loam with fine interstitial spaces, which will permit not too rapid percolation, and wherein the processes of nitrification may go on most thoroughly. Very dense clays may be rendered suitable by the admixture of sand or lime and by tile underdraining, and then will perform its office in a satisfactory manner. With a proper plant and intelligent supervision, the purified sewage makes a clear, bright, and practically sterile effluent.

In order to carry out the scheme so as to achieve the best results, the farm should be divided into three parts, not necessarily of equal area but of equal absorbability, each of sufficient capacity for the disposal of the entire sewage of a single day. Then each third may be worked in its turn, receiving sewage one day and resting two, but the capacity of none should be overtaxed, lest the soil become swampy and filthy, and cease the work of oxidation.

The farm is laid out in broad ridges and furrows, the latter receiving the sewage at regular intervals; the crops grow on the broad ridges between. It should be underdrained naturally or artificially at a distance of about six feet, so that the purified filtered water may be removed and allowed to discharge into any convenient water course.

The amount of daily dose per acre varies very widely according to pore-volume, permeability, and rankness of vegetation. On a close soil in a cold climate, but a few thousand gallons per acre can be discharged, while on an open soil in a hot country with rank vegetation, as in Madras, for instance, as much as 75,000 gallons daily will not be excessive. The chief crops grown are cabbages, mangolds, timothy, rye, and other grasses; in short, such as can bear heavy flooding of the soil.

As regards profit, it may be said that this system is the only one which can possibly yield a revenue, but this is not due to the supposed value of the manurial constituents of the sewage, but to the water itself, which puts the crops outside the danger of drought and beyond the need of rain. In some climates, crop follows crop the year round, and the annual yield is large; in others, the season is so short in comparison that the yield is much less. At the Berlin farms, a yearly yield of 25 tons of grass per acre, equal to 5 of hay, is regarded as large and satisfactory, while at Krishnampett in Madras, where eight crops per

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year are harvested, the output, according to Dr. J. N. Cook,[1] was in one year 69 tons per acre, equal to about 23 of hay, and worth nearly 200 dollars. The city of Berlin purchased and set aside 20,000 acres of land for its sewage farms, and, notwithstanding an outlay of more than 13,000,000 dollars for the entire plant, receives a yearly profit of 60,000 dollars from its operation, the labor costing nothing except for maintenance of the men engaged, these being condemned thereto for various minor misdemeanors.

Whether there be a profit or not, this aspect of the question should ever be kept in the background and the primary object ever in view. When the farms are let out to contractors, it is always advisable, and even necessary, that they be under the supervision of municipal authority, to insure that the public good is not subordinated to private gain.

It is not to be supposed that, even in very cold weather, the use of the system must be suspended, for when vegetation ceases, the soil continues the process of purification. At St. Laurent College, near Montreal, for example, the small sewage farm was found to act efficiently in disposing of the usual amount of sewage in a January (1898) temperature of —20° F.

Influence of Sewage Irrigation on Health.—Concerning the influence of sewage farms upon the health of those dwelling on and near them, the evidence is entirely on one side, and in opposition to what would naturally be supposed to be the case. It is the same from Berlin, Paris, Edinburgh, and the hundreds of other places where the system is in use, and all to the effect that in no way is it injurious. It is true that not infrequently the sewage gives rise to more or less disagreeable odor, especially if it be stored too long; but the fields themselves are generally quite free from nuisance, and even though odor be present, it produces no harm. At the Berlin works, in a population of more than 1,500, there was one death from typhoid fever in five years, the general death-rate was very low, and the zymotic death-rate exceedingly so; in fact, during one year it was *nil.*

Complete freedom from infectious disease is by no means unique, but is, indeed, a common condition in the experience of sewage farming. At the farms at Gennevilliers, where the sewage of Paris is received, the population is constantly increasing, the general health is excellent, and the general death-rate is low and continually decreasing. An extensive epidemic of typhoid fever in Paris would be supposed to be the forerunner of another of greater comparative severity where its sewage, containing all the bowel discharges and urine of sick and well alike, is treated, but experience has demonstrated that such is by no means the case, for in 1882, for instance, when Paris suffered from an unusually extensive outbreak of that disease, there was not a single case at Gennevilliers.

So far as is known, there is as yet no proof that sewage irrigation has ever been responsible in any way for the occurrence of extensive

[1] Indian Medico-chirurgical Review, Dec., 1895, p. 676.

outbreaks of typhoid fever, dysentery, or cholera, or, indeed, of entozoic trouble. Nor is there reason to look askance upon the products of the farms, despite assertions to the contrary based on surmise and inexperience, for the facts show that grass and other crops are of good quality, make good fodder, and bring good results in milk and butter when fed to cows.

Ferré[1] has, it is true, reported an outbreak of typhoid fever in a girls' boarding-school at Jurançon, which was presumably due to vegetables from a garden watered with the contents of an infected cesspool; and another localized outbreak of the same disease due to infected celery has been reported by the State Board of Health of Massachusetts. This occurred in September, 1899, at the Insane Asylum at Northampton, in which, prior to September 10th of that year, but 4 cases had occurred during ten years. Then cases began to appear, and in fifteen days the number had reached 39, and later a few more. Investigation proved beyond reasonable doubt that the outbreak was due to celery grown in beds which received the sewage of the institution. The method of banking employed in the cultivation of the plants made them a favorable medium for transmitting the disease. It should be noted, however, that neither of these outbreaks was due to produce from a large farm receiving the diluted sewage of a distant municipality.

Aside from local considerations of health, what are the results attained? This question can be answered in a few words. The organic matters of the sewage are destroyed completely by the saprophytic bacteria, which also dispose of their pathogenic brethren; the greater part of the water is taken up by growing vegetation and evaporated into the atmosphere, and the remainder in practically sterile condition sinks into the subsoil or is carried away by the underdrains and discharged into a stream. The effluent at Gennevilliers, for example, is organically purer than the original water before it becomes sewage.

The Waring System of Irrigation.—Irrigation on a small scale, known in this country as the "Waring system," is resorted to very commonly for the treatment of sewage of single houses and small settlements. As begun by the Rev. Mr. Moule, the inventor of the earth-closet, it was a scheme for the disposal of the liquid wastes which could not be cared for by earth-closets. The plant consisted of an open-jointed tile drain laid a little below the surface of the ground, parallel with and close to a row of grapevines. It was next enlarged by Mr. R. Field by the addition of a reservoir or flushing tank, shown in Fig. 90, by means of which the whole drain could be flooded throughout and intermittently. Brought to the notice of Colonel Waring, he adopted the system for his own house, and proceeded to improve it in several directions and to bring it into common use. Under him, the system was brought to its present state of perfection.

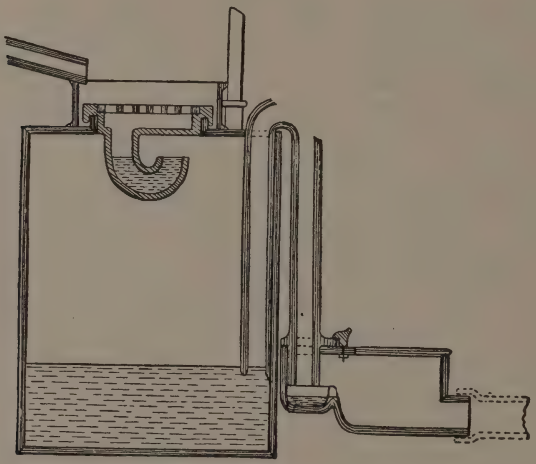
The plant consists of a reservoir into which the sewage runs, a wire screening basket to separate the paper and other matters not easily oxidizable, an automatic siphon by which complete discharge is secured

[1] Annales d'Hygiène et de Médecine légale, Jan., 1899, p. 23.

as often as the reservoir becomes filled, and a gate-chamber by means of which the flow is diverted to any of the three outlets, which lead to a miniature sewage farm. The drain pipes are laid, with open joints, not more than ten inches below the surface, and the ground where they discharge may be used for grassplots or gardens. The results are most satisfactory in every way; the organic wastes are oxidized by the soil bacteria, and the water which sinks into the subsoil is incapable of causing pollution such as occurs when cesspools with open bottoms below the zone of saprophytic bacteria are employed.

Within recent years, the tendency has been to do away with the drains where sufficient land is available, and to discharge the sewage directly upon the surface. Fresh sewage thrown upon grass is inoffensive, except to the sight, unless deposited in such amounts in the same place

Fig. 90.



Field flushing tank.

as to cause miring of the ground, cessation of oxidation, and consequent putrefaction. It is, of course, necessary that the screened matters be removed frequently and buried or burned, and that the reservoir be cleansed at regular intervals.

5. **Sewage Filtration.**—The method of intermittent filtration of sewage is the same in principle as the process described in the chapter on Water. Like that, it is more than a mechanical separation of suspended matters: it is a process of screening, oxidation, and eventually almost complete purification, much like sewage irrigation. As early as 1836, Bronner, of Heidelberg, endeavoring to learn the reason why the constituents of fertilizers in solution failed to reach the deeper layers of the soil, filled a bottle, having a small hole in the bottom, with sifted garden soil and poured in gradually a thick stinking manure juice, and observed the character of the effluent, which he found to be almost odorless and colorless, and devoid of fertilizing properties.

But the system of sewage purification by this means had its beginning within recent years at the experiment station at Lawrence under the direction of the Engineering Department of the State Board of Health of Massachusetts, and is now in actual use by many municipalities in this country and abroad. The filter beds are made best of sand, not finer than 0.2 mm. grain size, and gravel. Ordinary loams, clays, and peat are practically useless as filtering materials, on account of the difficulty with which water passes through them. The purifying agents are the bacteria which are soon established within the interstices, and these include both anaërobic and aërobic varieties. In order that both kinds may perform their office, the application of the sewage should alternate with thorough aëration of the bed. Unless the application be intermittent, the anaërobic action alone is encouraged and the process fails. Where sand of the right sort is not obtainable, many other materials as coke, burnt clay, coal dust, and cinders, have been used as substitutes.

It is unnecessary to disturb the main body of the filter after the process has been started; but on account of the tendency of solid materials, such as paper, etc., to accumulate in the upper layers, it is found necessary to rake or dig over the surface as often as the indications point out. According to Mr. X. H. Goodnough,[1] of the Engineering Department of the State Board of Health of Massachusetts, the beds of four of the filters at the Lawrence station, after ten years' continuous operation, required only a weekly raking and a semi-annual spading to a depth of six to eight inches. In five years, it had not been necessary to remove any of the clogged sand for renewal of the surface. During the tenth year, more than 90 per cent. of the organic matter of the very strong Lawrence sewage was removed, and also more than 99 per cent. of the contained bacteria.

It has been shown by the experiments at Lawrence that 100,000 gallons of crude sewage per day may be purified during all but the colder months of the year by each acre of filter underdrained at a depth of three to five feet. And even in winter, there is no great difficulty in disposing of almost as large volumes if the beds are properly looked after, and provided the sewage is delivered in large volumes at a time. With delivery of small quantities, there is more danger of freezing.

It should be borne in mind that the sewage of many kinds of manufacturing establishments is not suited to sand filters or other processes which depend for their efficiency on micro-organisms, because of containing chemicals which will destroy the life of these necessary agents. Thus, in the single industry of tanning, at least two substances are used which interfere with bacterial growth. In the first place, green skins are quite likely to be preserved by means of chemical disinfectants (sulfonaphtol), and, in the second place, when the skins are soaked preparatory to having the hair removed, large quantities of chemicals, such as arsenic sulphide and lime, mixed together, are used to facilitate the process. Sewage containing these substances in sufficiently large

[1] Journal of the Massachusetts Association of Boards of Health, July, 1898.

amount, if applied directly to a sand filter, will quickly interfere with its efficiency by destroying the nitrifying organisms. Sewage from this industry contains, in addition, such a very large amount of organic matter in suspension, that if applied directly to a sand filter, it will cause clogging very quickly. Hence this and other industrial sewage of objectionable character should be submitted to sedimentation or other treatment, according to its nature, as a preliminary to sand filtration. It has been found that arsenic, for instance, may be removed completely by passing the sewage through coke breeze. "The removal is probably due to a combination of the arsenic with the iron in the coke, and the formation of an insoluble double salt of iron and arsenic, which is retained in the coke."[1] Filtration through coke has also been found efficient in removing the organic matters, even when the sewage is applied at the rate of 250,000 to 300,000 gallons per acre daily. Other kinds of industrial sewage may contain other objectionable substances which may tend to clog the filter, as grease, soap, and other materials, and these may require special treatment. The importance of guarding against injury to the nitrifying organisms by special sewages should be borne in mind, and also that if the process be stopped in winter, it cannot be renewed until the return of warm weather.

6. **Other Biological Processes: Dibdin's "Bacteria Bed." Cameron's "Septic Tank," etc.**—As an outcome of experiments in the farther purification of the effluent of chemically treated sewage, sprang the method known as that of **Dibdin's Bacteria Filter.** With the idea that purification in a filter bed is not brought about wholly at the surface, but that the whole bulk of the filter is concerned therein, experiments were made to determine the result of filling a bed and restraining the outflow for different periods, thus giving the organisms throughout the bed the same opportunity for action. When the contents were allowed to run off through the underdrains, the interstices of the bed became filled with air by inspiration, and after standing thus for a time, the process of filling, standing, and emptying was repeated continuously for six days, and then an interval of twenty-four hours was allowed for complete aëration. The results obtained were most promising. During the first month, running at the rate of half a million gallons daily, the purification, measured by the albuminoid ammonia, ran between 70 and 80 per cent., and after a full month reached 83 per cent. The effluent was then so pure that fish, placed in it, lived many weeks. Later on, the plan adopted comprised two hours for filling, one for standing full, and five for emptying, so that the cycle was completed in eight hours. Passing filtrate at the rate of a million gallons a day for eight weeks, the bed was found to show 78 per cent. of purification. The good results were observed to be yielded even when the weather was so cold that ice formed on the surface. From these experiments it appears, therefore, that the purifying capacity of a filter may be expressed in terms of cubic as well as of surface measure.

[1] Report of the State Board of Health of Massachusetts for 1896, p. 430.

In consequence of the favorable results of these experiments, Mr. Dibdin recommended similar treatment for crude sewage, and in November, 1896, the process was instituted at Sutton. An average of 29,165 gallons per day, equal to 773,000 gallons per acre per day, was treated with good results, the purification amounting to 66 per cent. The effluent was treated farther on other beds, and thus a total reduction of 86.5 per cent. was brought about. The effluents were nearly inodorous; the slight odor suggested freshly turned garden soil. During the 76 days of observation, the suspended solids disposed of by bacterial agency amounted to the equivalent of more than a ton of sludge daily, so that not only was purification effected much more simply and cheaply than by chemical treatment, but the annoying and expensive matter of sludge disposal was done away with entirely.

For the disposal of a million gallons of sewage per day, Mr. Dibdin[1] recommends as follows: Before being passed on to the beds, the sewage should be screened, in order to remove mechanically as much of the suspended matters as possible, and these may be burned or buried. The finer solids "if placed upon a filter constructed in the ordinary manner with a stratum of fine material upon the surface, will at once form a layer of slimy mud, impeding the progress of the water into the pores of the filter, and preventing the entrance of air so necessary for the healthy life processes of the bacteria, with the result that in a short time the whole mass becomes putrid, and the 'filter' is a failure.

"The first set of bacteria beds should, to be on the safe side, have a collective capacity of 160,000 cubic feet, divided into, say, nine partitions. These beds should be filled with either coke, burnt ballast, or other suitable substance which has been rejected by a half-inch mesh, in order to exclude dust and small stuff, and thus lessen the chance of clogging from the accumulation of sludge and the zoöglea form of bacteria, which, by its gelatinous character, under favorable conditions might develop to a sufficient extent to assist materially in rendering the filter water-logged. . . . In addition to this set of beds filled with coarse stuff, a second series of the same capacity should be constructed at such a level that they can be filled without pumping from the first. These should be filled with the fine coke or ballast passed by the sifting in the first instance, but the fine dust should be rejected.

"If it should be desired to obtain a still more perfect effluent, and thus to realize the ideal of perfection, namely, an approach to drinking-water, another set of filter beds of the same area as the foregoing may be provided in those cases where the levels permit, and filled with very fine breeze or fine sand, such as that used by the water companies." The beds of each series are to be filled in order, and when No. 8 is filled, No. 1 is ready for its second charge, and so on. Allowing one hour for filling, two for resting full, one for emptying, and three for resting empty, each bed can receive three changes in twenty-

[1] Purification of Sewage and Water, London, 1897, p. 129.

four hours. The ninth bed is to be held in reserve to replace any one which may be thrown out of action, and "it would be a useful arrangement to systematically throw one tank out of action each day, thus giving them all a day's rest once in nine days." The efficiency of the various beds may be determined occasionally by testing the filtrate for nitrates, the presence of which in fairly regular amount is evidence of unimpaired activity.

According to Dr. Clowes,[1] the first effluent of the experimental coke beds at Crossness for the treatment of London sewage is of such a character that fish can live in it for months. The whole of the suspended matter and 51.3 per cent. of oxidizable and putrescible matters are removed by a single treatment. Double treatment raises the percentage from 51.3 to 69.2. The deposition of cellulose in various forms, as cotton, paper, woody matters, straw, and chaff, which matters do not appear to be acted upon to any extent by bacteria, causes considerable clogging of the interstices, and hence reduces the capacity of the filter. It was estimated that the reduction amounted to about a third in ten months.

At Sutton, it should be said, there is a catchpit to intercept the heavier matters, and also a very efficient screening machine; and since the sewage comes down in so fresh a condition that neither the paper nor the solid fæces have had a chance to disintegrate, a very large percentage of organic matter never reaches the filter at all.

The Cameron "Septic Tank" process is one in which the anaërobic bacteria are first utilized for the purpose of hastening decomposition of the organic matters. Contrary to the general opinion that sewage ought always to be treated before the beginning of putrefaction, in this system the sewage is kept in storage tanks out of contact with light and air until the organic matter is broken down, and then is passed on to bacteria beds, where the aërobic forms continue the work.

The first attempt at purification of town sewage by this system was instituted at St. Leonard's, a suburb of Exeter, England, by Mr. Donald Cameron, whose initial plant consisted of an underground covered tank, sixty-four feet long, eighteen feet deep, and of an average depth of a little more than seven feet, and five Dibdin bacteria beds filled with coke breeze and clinkers. The crude sewage, before entering the tank, passes first into a grit chamber, which is three feet deeper than the tank, and in this the heavy matters fall and are detained, but may be removed without interruption of the process in operation within the tank. The sewage is not screened in any way, and enters the tank, after passing the grit chamber, by inlets placed five feet below the surface. These are so placed for several reasons: the scum floating on the surface is not disturbed, gases from the tank cannot escape backward, and air cannot enter the sewage. In the tank, the sewage undergoes putrefaction, the organic matters being broken up into simpler soluble forms and in great part converted to

[1] Bacterial Treatment of Sewage. Second Report. London County Council, 1899.

carbon dioxide, sulphuretted hydrogen, ammonia, nitrogen, and other gases. The flow through the tank is continuous, and the effluent passes off through outlets located at the farther end at the same level as the inlets. In the center of the tank, an inspection chamber of brick and thick plate glass is constructed, and from this the processes going on may be observed. At the surface of the liquid, a scum about two inches in thickness, consisting of flocculent matter in various stages of decomposition, is formed, much of it brought up from the bottom by gases formed in the process of decomposition. Throughout the tank, countless small masses are seen rising through generation of gases and falling by their own weight. Every time a particle rises or falls, it loses in volume, and finally it disappears. The effluent from the tank, brownish yellow in color and offensive in odor, is next admitted to the bacteria beds, where the nitrifying organisms perform their share of the work. In its journey to these beds, it passes in a thin layer over the sides of troughs closed at both ends, and thus becomes aërated by contact with the air. By an automatic arrangement which regulates the flow, one bed remains full while another is being filled, and after a certain time is allowed to empty. Four beds are kept in use, the fifth resting for a week. Each bed, then, is in operation four weeks out of every five, and after its week of rest, takes the place of the one which has been longest in use. The accumulation of sludge in the tank is very slight. It amounted to but fifteen inches at the end of ten months' trial, during which time more than 17,000,000 gallons of sewage were treated.

Analysis has shown that the organic matters in solution are reduced in amount nearly a third and the suspended matters more than a half by bacterial action within the tank, and that, after passing through both the tank and the bacteria beds, the sewage loses practically all of the suspended matters, and more than 80 per cent. of the oxidizable organic substances in solution. The effluent from the beds is fairly clear and sufficiently pure to warrant its discharge into a water course. It is claimed even that it is fit to drink.

The advantage of the tank lies in the reduction in the amount of suspended matters, whereby less clogging of the surface of the bed occurs, and in relieving the beds of much of the work of disposing of organic matter by nitrification. The cost of working is, moreover, very slight, inasmuch as the apparatus, by reason of its ingenious system of automatic gears, requires little supervision. It is said that, with this system, as much as 363,000 gallons per acre of bacteria beds can be disposed of daily without nuisance.

The Scott-Moncrieff System, introduced in 1896, at Caterham, England, consists of a tank filled with broken flints and other coarse material resting on a perforated bottom, and a filter consisting of a series of trays containing coke. The sewage enters the tank continuously beneath the perforated bottom, passes upward through the flints, and in its passage is subjected to the influence of the anaërobic species of bacteria alone, excepting that, at the surface, the action is aërobic to

a slight extent. It passes thence to the upper trays of the filter, where the action is wholly aërobic, and flows continuously downward from tray to tray, becoming more and more oxidized and nitrified, the resulting effluent showing a very high degree of purification. The system possesses no advantage, however, over the septic tank, which, by reason of the absence of filling material (flints, etc.), has greater capacity for sewage, and which, therefore, may be operated at lower cost.

CHAPTER VII.

DISPOSAL OF GARBAGE.

GARBAGE comprises all manner of waste material, and its disposal is of very great economic and sanitary importance. The daily accumulation in towns and cities is enormous, and its removal at regular intervals is a matter of great concern to municipal administration. From a hygienic standpoint, the proper disposal of kitchen waste and other decomposable material far outweighs in importance the removal of such matters as waste paper, ashes, discarded boots and shoes, tin cans, bottles, and other rubbish, which in no way can affect the public health, but which for various reasons, may not be allowed to accumulate in the household. In rural districts, the disposal of garbage in general is exceedingly simple; but in crowded communities it entails great expense, and is usually a very complicated problem. Since this work is concerned solely in matters of sanitary interest, and not in economics, the consideration of this subject will be restricted to the methods of disposal of those matters, the retention of which on occupied premises may be regarded as detrimental to health, namely, those known as kitchen refuse, or swill.

The methods of disposal of these matters comprise those which may be carried out by the individual householder on the spot, and those adopted by municipal authority after house-to-house collection.

In many households, refuse is disposed of by burning in the kitchen fire with or without a preliminary process of drying, for which a number of simple apparatuses have been devised. A very efficient arrangement in common use consists of an enlargement in the lower part of the stovepipe, forming a chamber into which, through a doorway in the end or side, the refuse, in a suitable metallic holder with perforated sides and bottom, is introduced. Through this the hot air, gases, and smoke from the fire pass on their way to the chimney flue, and thus complete drying and partial carbonization are brought about. The dried residue is disposed of finally by burning in the stove, where it serves a useful purpose as fuel.

In country and suburban districts, kitchen waste is advantageously disposed of by feeding it in a fresh and sweet condition to swine and poultry, and depositing in the soil such matters as they will not eat. Burying in the soil is a simple and effective method of disposal, entailing but little labor, since it is best not to deposit it very deeply. Near the surface, decomposition occurs rapidly, and so a covering of earth a few inches in depth is sufficient to prevent contamination of the atmosphere with noisome odors.

The methods adopted by municipal authorities comprise dumping into the sea, disposal to farmers for swine-feeding, utilization as food for herds of swine kept for the purpose, and reduction and incineration in furnaces of special construction, known as destructors.

Dumping into the sea is open to the objection that, under favoring conditions of winds, tides, and currents, much material may be washed ashore, and become a nuisance and eyesore to the immediate neighborhood.

Disposal to farmers involves cartage over miles of road in wagons, which, if not leaky for liquid matters, at least permit the escape of nauseous odors, to the annoyance of dwellers and travellers along the route. It involves, also, storage for at least a short time after collection, unless the garbage wagons can themselves be sent into the country—a proceeding which can hardly be regarded by taxpayers as consistent with the proper management of municipal revenues. This period of storage is, in effect, a continuation of that which has, perhaps, extended already through several days or a week before collection, during which time, various fermentative processes have been active in the production of compounds of offensive character.

Incineration at special stations for the destruction of swill and all other combustible rubbish is being widely adopted by large communities, and, in many places, has proved to be not only the most economical method of disposal, but even a source of gain. To such a station are brought the daily collections of garbage, which at once undergo a process of sorting. Paper and pasteboard are utilized in the furnaces as fuel or are sold to be used in the manufacture of the cheaper grades of paper and cardboard ; old shoes and boots are disposed of to makers of artificial leather, and rubbers and overshoes to manufacturers of rubber goods ; tin cans are heated to recover the solder ; pieces of unconsumed coal are collected and used or sold for fuel ; broken furniture, boxes, barrels, and other wooden objects are split up into kindling, and excelsior stuffing is utilized in the furnaces. In short, almost every kind of rubbish may be utilized in some way to advantage. The late Colonel George E. Waring, Jr., experimenting in New York with a long travelling belt, on which the combustible waste from a district containing 200,000 people was deposited and picked over, found that 90 per cent. of it was salable, and but 10 per cent. remained to be destroyed by fire. In some establishments now in operation, a long, travelling, endless belt of steel plates is employed, the carts dumping upon it at one place. As the material passes along, it is sorted over quickly by men on either side, and what is left is conveyed onward to a bin, from which, in time, it passes to the furnace, to serve to destroy the kitchen waste.

It would be impossible, even if it were not unnecessary, to give in detail a description of the many varieties of machines and furnaces which have been invented for the incineration of refuse. In general, it may be said that a destructor consists of a furnace with a chamber, provided with grate-bars, in which the dry or partially dried

offal is burned; and a second chamber, in which it is subjected to a preliminary process of drying. This second chamber is placed behind the front compartment, which receives the dried garbage and other combustible material serving as fuel. In the best forms, two fires are maintained: one at the forward end, and the second at the stack end of the furnace, the latter being designed to insure complete combustion of vapors and dust before entrance to the chimney, from which, otherwise, they might issue in such a form as to create serious nuisance, not alone to the immediate neighborhood, but even at considerable distances.

The burning of the smoke and fumes is very essential, and failure to provide therefor, or the unsuccessful operation of the fume cremator, has caused the abandonment of many plants, which, with better installation, should have worked successfully and to public satisfaction. In many English cities, destructor furnaces have been in operation for years in close proximity to dwellings, schools, and hospitals without causing offence. At Ealing, for example, the furnace is located at a distance of 180 yards from two hospitals; in Whitechapel, within a very few yards of dwelling houses in the midst of a very populous district; at Leicester, but a very few yards from a large school and immediately adjoining a considerable number of dwellings.

The fume cremator consists of a reverberatory arch with rings of firebrick, placed in the direction taken by the gases. Projecting ribs deflect the vapors to the top of an intensely hot fire, in which they are destroyed. Provision is made for rapid removal of ashes, and for drafts of air at needed points to maintain a continuous temperature above 2.000° F. The heat produced is commonly utilized in the production of steam for the engine which does the necessary hoisting and other work, and drives the shafting connected with the endless belt and other appliances. Another most useful and economical application is the utilization of the great store of energy for maintaining electric-light plants for lighting the premises, and even the public streets. In New York and Boston, the surplus energy is utilized, but at most other plants in the 54 cities and towns of this country which, in 1899, were using the process, the heat is wasted.

At the beginning of 1899, 81 communities in Great Britain were employing incineration as the chief means of disposal of refuse, and 76 of them turned the developed heat to some useful purpose. About a third of the number use the power for electric lights for the works or streets, or both together; nearly two-thirds maintain mills for grinding materials for mortar and clinkers for pathways; six employ the steam for the purpose of public disinfection; several, for pumping sewage, and others, for various useful purposes. In one city, 3,000,000 gallons of sewage are pumped through a twenty-foot lift, the works are lighted by electricity, the shops and forges of the municipal service are supplied with power, and other work also is performed.

Reduction.—In the reduction process, the kitchen garbage is stored in tanks which permit the draining away of most of the water, which

is conducted directly to a sewer. Next it is dried in cylindrical steam-jacketed chambers, into which hot air and superheated steam are conducted, the process requiring about six hours. The material loses about three-fourths of its weight, which passes off in the form of aqueous vapor and is condensed and discharged into the sewer; the non-condensible stinking vapors are disposed of in the vapor cremator connected with the boilers in which the steam is generated. The dried residue is next introduced into tanks of naphtha, and the whole is heated by steam coils until all grease has been removed, when the naphtha solution is separated. This is then distilled, the naphtha passing over and being reclaimed for repeated use, and the fat remaining behind as a valuable product. The extracted residue is dried again and worked up into fertilizer.

Reduction methods are applicable only to large cities, and since it is almost impossible to conduct the works without creating a nuisance, these should be located at such a distance from a community that the value of property may not be impaired, and the daily enjoyment of life may be in no way sensibly abridged. If the amount of collectable kitchen waste is sufficiently large, say that from a population of at least 150,000, and if the works can be so placed as to cause no nuisance and, at the same time, not to necessitate a long and expensive haul of the material, reduction has been found to fulfil both the sanitary and the economic requirements, the yield of grease and fertilizer having considerable value, thus reducing materially the cost of disposal. But, as in the case of sewage, it should be borne in mind that the removal and disposal of waste are sanitary measures, and should not be viewed too much from the standpoint of profit-making.

If the quantity of garbage collected is too small to warrant treatment by reduction processes, it may be burned to advantage in destructors. A combination of the two methods, reduction and cremation, would seem to be the most advantageous for communities producing a very large daily amount of general wastes. But the possibility of nuisance from all reduction works, a nuisance which has caused the abandonment of the great majority of the plants which have been installed in this country, should ever be borne in mind, even though the nuisance be limited to a small percentage of the population, who, if they complain, are regarded by the rest as unduly sensitive, prone to magnify small discomforts and give them a factitious importance, and inconsiderate of the general welfare, which, even if true, can not deprive them of their right to appeal to the courts for the abatement of the cause of their discomfort.

CHAPTER VIII.

DISINFECTANTS AND DISINFECTION.

Disinfectants, or germicides, are agents which bring about the destruction of bacteria in general, and, more particularly, of those that act as the exciting causes of disease. While they are all to be classed as antiseptics, the latter, as a class, are by no means necessarily disinfectants, since many of them act simply to delay or prevent the action of fermentative agents, without exerting any destructive influence upon them. Cold, for example, is a most efficient antiseptic; but while it may inhibit growth and activity of micro-organisms, it does not necessarily deprive them of vitality.

Deodorants are agents which remove or mask disagreeable odors, but they are not necessarily disinfectants. Some deodorants are efficient disinfectants, but not all disinfectants are efficient deodorants. The latter are largely substances which, being of strong, peculiar odor, are used to overcome or supersede disagreeable odors, but without exerting any influence upon the causes thereof. Odors may or may not be a concomitant of infectious matter according to circumstances; and when so, the mere fact of their being overwhelmed by a more powerful rival smell has no influence on the vitality of the bacteria present. Some deodorants remove smells without the creation of another, and without exerting any action upon their causes; such are charcoal and ordinary earth.

The function of disinfectants is the destruction of morbific agents so that they shall not spread infective diseases. They are not curative of the infected person, but are preventive of the spread of the disease from that person to others. An efficient disinfectant for general purposes should possess the property of killing not this and that species of bacteria, but one and all, and their spores as well. Some pathogenic bacteria have a tolerance for certain disinfectants, and may acquire one gradually for certain others. Such agents cannot, therefore, be included among the efficient class for general use. For special work in destroying the infective agents of certain diseases, disinfectants which have been proved to exert a destructive influence on the particular organisms may be used, although they have failed to show an equal power against other, more resistant, varieties. Disinfectants may be divided into two classes, namely: 1. Physical agents. 2. Chemical agents.

PHYSICAL AGENTS.

The physical agents are: 1. Light. 2. Heat.

Light.—Direct sunlight is one of the most important disinfectants known. It retards the growth of many organisms, and, after a vary-

ing number of hours of exposure, completely destroys the vitality of a number of the most important pathogenic bacteria, including some generally recognized as highly resistant. Diffused daylight and electric light also are effective, but in a much diminished degree.

Koch[1] announced, in 1890, that the bacillus of tuberculosis is killed by direct sunlight in from a few minutes to several hours, according to the thickness of the layer of material in which it is exposed, and by diffused light in from 5 to 7 days. Dr. Franz Migneco[2] exposed tuberculous sputum on linen and woollen fabrics to direct sunlight, and found that, provided the layer was not too thick, the bacilli could not resist longer than from 24 to 30 hours. The virulence was observed to diminish gradually after 10 to 15 hours, and to disappear completely after 24 to 30 hours.

Janowski,[3] experimenting with the typhoid fever bacillus, discovered that that organism failed to grow when planted in bouillon and exposed for 6 hours to direct sunlight; and that, in bouillon, exposed 8 hours out of every day to diffused light and kept in the dark the rest of the time, its development was much delayed, but in the same medium, kept wholly in the dark, cloudiness was observed in from 16 to 20 hours. That this action is not due to increase in temperature, was shown first by Saverio,[4] who exposed gelatin cultures of the organisms of typhoid fever, anthrax, and cholera, and *Staphylococcus pyogenes aureus*, to sunlight and electric light for from 2 to 47 hours, and made careful observations of the temperatures within the tubes. He discovered that the most energetic action was not coincident with high temperatures, although the latter hastened the beginning of the process. The action of electric light was much less energetic than that of direct sunlight. Anthrax spores were destroyed almost as quickly as the bacilli, and after a certain length of time their virulence progressively diminished. The red and infra-violet rays appeared to exert no bactericidal properties.

Geissler[5] found that direct sunlight exerts a more powerful influence on cultures of the bacillus of typhoid fever than an electric light of a hundred-candle power at a distance of a meter, and advanced the proposition that the effects on the bacteria are due in part to changes brought about in the character of the culture media. That the action of sunlight is chemical, is shown by the differences in the capacity of the different rays for producing results, the ultra-violet being endowed with the greatest power.

This change in the character of the culture media has been noted also by Kruse,[6] who found that liquid media, containing complex nitrogenous substances, are so altered by the influence of light that they acquire

[1] Vortrag auf dem zehnten internationalen medicinischen Congresse, 1890.
[2] Archiv für Hygiene, XXV., p. 361.
[3] Centralblatt für Bakteriologie, VIII., p. 6.
[4] Annali dell'istituto d'igiene sperimentale della reale universita di Roma, II., Serie 2, p. 121.
[5] Centralblatt für Bakteriologie, XI., Nos. 6 and 7.
[6] Zeitschrift für Hygiene und Infectionskrankheiten, XIX., p. 313.

antiseptic properties against the bacteria, and that the change is proportionate to the intensity of the light and the duration of the exposure. It is due directly to the atmospheric oxygen, which, according to Momont,[1] is simply assisted by the light, which by itself would have but little effect But it is not alone through changes in the media that bacteria are killed, but through changes brought about within themselves as well And, indeed, it has been demonstrated that not alone bacteria, but their toxins also, are affected. According to Fermi and Celli,[2] the toxin of tetanus, diluted with distilled water and exposed to direct sunlight at temperatures between 40° and 50° C., is rendered inert in 8 hours, and at 37° C., in 15 hours. In dried condition, it loses its power after 4 hours.

Moisture and access of air are also important factors, as has been shown by Momont, who found that anthrax bacilli in a moist state were killed in 2.5 hours with free access of air, and survived more than 50 hours when air was excluded. Dry bacilli were killed with access of air in 5 hours; dry spores, exposed in glass without air, were virulent after 110 hours, and proved to be more resistant than others in a moist state.

The rapidity of action of sunlight is influenced also by the number of bacteria present — the greater the number, the longer the time required for the bactericidal effect to be instituted.

The sterilizing influence of sunlight on the bacteria of drinking-water and sewage has been demonstrated by Procaccini, Buchner and Minck, and others to be very considerable, especially at and near the surface. Procaccini[3] obtained positive results at a depth of from 26 to 30 centimeters. Minck and Buchner[4] found that water containing 100,000 *B coli communis* to the cubic centimeter was rendered sterile in an hour. The bacilli of typhoid fever and cholera, and *B. pyocyaneus* also were found to be destroyed. Cultures of *B. typhosus*, exposed at a depth of about 5 feet, were sterilized in 4½ hours, but at twice that distance beneath the surface the action virtually ceased. Buchner[5] found, farther, that diffused light has a strong influence, even as late in the year as November, on *B. coli communis* and *B. pyocyaneus*. The action of light is considerably interfered with by particles in suspension, but with fairly clear water the effects are perceptible at a depth of about 6 feet. The action of sunlight on bacteria in the presence of water is believed by many to be due to the production of hydrogen peroxide.

The obvious disadvantages of relying upon sunlight for practical disinfection are that its supply is beyond control, and that, even on the brightest days, it is impossible to apply it to all parts of a house. Nevertheless, its beneficent action may, under favoring conditions, be

[1] Annales de l'Institut Pasteur, 1892, p. 28.
[2] Centralblatt für Bakteriologie, XII., No. 18.
[3] Annali dell'istituto d'igiene sperimentale della reale universita di Roma, III., p. 437
[4] Centralblatt für Bakteriologie, etc., XI., p. 781.
[5] Archiv für Hygiene, XVII., p. 177.

taken advantage of in the treatment of furniture, hangings, and decorations, often the most troublesome objects to disinfect, especially in a country practice.

Heat.—For purposes of disinfection, heat is employed as "dry heat," *i. e.*, hot air, and "moist heat," *i. e.*, steam and boiling water. Steam is employed under various pressures in both the saturated and superheated conditions. In both conditions it is actually dry, although, as very commonly understood, saturated steam is associated with the idea of moisture. "Wet" steam is partially condensed saturated steam, and contains suspended particles of water. The temperature at which steam is formed depends upon the pressure; and whatever the temperature and pressure, as ebullition begins and proceeds, the water is maintained at that temperature, and is converted constantly into steam, in which the heat employed becomes latent. Until all the water has become converted, the resulting steam is said to be *saturated*, since any vapor in the presence of the liquid from which it originates and in thermal equilibrium is necessarily saturated. In the saturated state, it can neither do work by expansion nor be cooled without undergoing partial condensation.

When saturated steam is farther heated, its temperature rises, and it is then known as *superheated;* and then, having a temperature higher than the condensing point corresponding to its actual density and volume, it may be cooled and can do work by expansion without being condensed. When very much superheated, it behaves more and more like a perfect gas, while saturated steam differs, as a rule, considerably. If water at the temperature of superheated steam be mixed with the latter, some of it will be vaporized and taken up; but mixed with saturated steam at the same temperature, no such action will occur.

According to Rideal,[1] the first recorded experiments in the sterilizing of organic matter by the application of heat were those of Needham, made prior to and during the year 1743, and the first application of this agent to disinfection on a large scale was made in 1831 by Dr. Henry, F.R.S., who treated infected clothing with hot air, and showed that the clothing of scarlet fever patients, subjected to a temperature of 200° F. for two to four hours, would not propagate the disease if worn by healthy persons. The first use of direct steam as a disinfectant was made under the direction of Dr. A. N. Bell, U.S.N., in the case of the steamer *Vixen* and schooner *Mahones*, which were infected with yellow fever while on service in the Mexican war in 1848. Knowing of this use and its observed results, at the Quarantine and Sanitary Convention held in Boston, Mass., in June, 1860, the committee recommended that "steam generators and steam jackets or vats be provided for the disinfection of all personal, hospital, and ship's clothing and bedding, together with such other infected goods or things as may properly be subjected to high steam heat."[2]

In 1862, according to Dr. Bell, the U. S. Transport *Delaware* was

[1] Disinfection and Disinfectants, London, 1898, p. 20.
[2] The Sanitarian, June, 1897.

disinfected by steam at the New York Quarantine Station on account of yellow fever, this being the first disinfection of a vessel at that station, and probably the first at any of the port quarantines. According to the same authority, Commander Ralph Chandler, of the U. S. S. *Don*, from Santa Cruz, W. I., reported to the Navy Department that his vessel had been infected with yellow fever in its worst form (23 cases with 7 deaths), and that he had disinfected the ward room and berth deck successfully by means of steam. He recommended that vessels destined for service in the West Indies be provided with means of steaming the lower decks and holds.

Dry Heat.—Dry heat is much less effective than moist heat, even at much higher temperatures and with longer exposure. Thus, air at 300° F. requires three or four times as long to accomplish the same work as steam at 212°, and possesses the additional disadvantage of injuring fabrics and other objects exposed to it. Most fabrics of cotton, linen, and silk will withstand an exposure of several hours to dry heat at 230° F., but beyond this point, evidence of impaired tensile strength is soon manifested. Even at 302° F. (150° C.), dry heat was found by Koch and Wolffhügel to be not always effective, even after two hours, while boiling water and streaming steam at 212° F. were found to produce the desired results in a very short time. But Schumburg[2] has shown that air heated to 212° F. will destroy the common non-sporing pathogenic bacteria if it contains 55 to 65 relative humidity. This condition can be secured by placing pans of water within the space where the infected objects are treated.

Steam.—Although steam had been recommended and used for purposes of disinfection as early as 1848, and although Pasteur, Tyndall, Cohn, and others had demonstrated in a number of extensive scientific investigations the sterilizing action of moist heat on putrefactive bacteria and other micro-organisms, and Tyndall had shown the necessity of discontinuous boiling for the sterilization of spore-bearers, the first investigation of the action of steam on the vitality of the bacteria associated with infective diseases was that conducted by Koch, Wolffhügel, and their associates, the results of which were published in 1881. They demonstrated the very great superiority of steam over much hotter air, and showed that the most resistant spores are destroyed within a few minutes. They studied its effects on the different kinds of articles, such as clothing, bedding, furniture, and other objects, which in sanitary practice may require to be disinfected, showed its applicability to all excepting a limited number, such as furs, leather, and veneered furniture, and led the way to the installation of public disinfecting plants for municipalities, hospitals, and quarantine stations.

A variety of apparatuses, both fixed and portable, have been devised, and their use is steadily on the increase, not alone in large communities, but, especially in Europe, in thinly settled districts as well. For the latter, the portable apparatus on wheels is especially adapted, for it is

[1] Mittheilungen aus dem kaiserlichen Gesundheitsamte, I., p. 301.
[2] Zeitschrift für Hygiene und Infectionskrankheiten, XLI., p. 167.

beyond the limits of reason to expect small towns in which, perhaps, infective diseases of the kinds that call for thorough disinfection are only occasional visitors, to establish and maintain public stations, whereas a number of such communities may have joint ownership in a portable machine which may be despatched on demand to the point where its services are required.

The general plan of the stationary and portable machines is essentially the same. They consist of one or more chambers of sufficient size to admit objects as large as or larger than a rolled mattress; and a boiler for the generation of steam, which is admitted through pipes controlled by valves. The most approved machines are so constructed that, after the objects have been introduced and the doors closed, the contained air may be withdrawn and a partial vacuum of about 20 inches produced, the object of which will be explained later. This is produced best through the agency of a steam jet rather than by a pump, since the latter is much slower in achieving the same result and exerts no disinfecting action on the germs that are contained in the air withdrawn. The best machines are provided also with a steam jacket, which assures a more uniform diffusion of heat in the chamber walls and a lessened opportunity for condensation, and a non-conducting outside casing of asbestos or asbestos-magnesia composition, to prevent loss of heat.

The apparatus in use at the New York Quarantine Station may be taken as a type of the most approved construction. It consists of a chamber of steel, the inside dimensions of which are 4 feet by 3 feet 3 inches by 7 feet 2 inches, with an outer shell of the same material, and an intervening space of 2 inches. The outer shell is encased in a layer of asbestos-magnesia, 1.5 inches in thickness, for the prevention of loss of heat. At each end is a door, made to fit air-tight, swung on a crane, and fastened to the chamber by means of turn-buckles. Within the chamber is a movable track so arranged that the car, made of 1.5 inch angle-iron and No. 6 galvanized iron netting, for the reception of articles to be disinfected, may be withdrawn at either end.

The steam from the boiler enters the chamber through a 2.5 inch pipe at a pressure of 15 pounds to the square inch, or at such other pressure as may be desired. By means of a steam exhauster, controlled by valves, a vacuum may be produced in one minute either in the chamber or in the space between the two steel shells. A fresh-air inlet, consisting of a 1.5 inch pipe provided with a valve by which it is opened and closed, and with a fine brass netting for the exclusion of matters which otherwise might gain entrance, connects the chamber at its upper part with the external air.

The apparatus is so disposed that the ends of the chamber open into rooms having no communication with each other, one being for the reception of infected articles, and the other for their delivery after they have been disinfected.[1] The articles to be treated are placed in

[1] The foregoing description of the apparatus and the following account of the method of operation are abstracted from Assembly document No. 58, "Disinfection by Steam," by Dr. A. H. Doty, Health Officer of the Port of New York.

the car in the special room for their reception, the door is then bolted, and a vacuum of 20 inches is obtained by the steam exhauster. This removes the air from the chamber, and also the air and moisture from the material to be treated, which, forming a cushion, would prevent the proper entrance of the steam. Steam is then admitted very rapidly, and a temperature of 230° to 240° F. is attained within 3 or 4 minutes. After 15 minutes' exposure, the steam exhauster is again brought into play, and a vacuum of 20 inches is again secured. The fresh-air inlet is then opened, and by means of the steam exhauster a current of air is drawn through the chamber and its contents for 8 or 10 minutes. The door communicating with the second room is then opened and the articles are removed, unrolled, and exposed for 3 or 4 minutes, at the expiration of which time they are completely dry, and may be taken away.

According to Dr. Doty, "The degree of improvement in the drying process, which is the result of the combined action of the steam exhauster and the fresh-air inlet, can only be appreciated by one who has waited two or three hours or more for this same result. . . . The importance of the rapidity with which this work is now performed and the material dried is especially appreciated in the treatment of mail," in which a letter unsealed or partly unsealed is very rarely, and with the superscription affected is never, found. This satisfactory result is due to the rapid action of the heat, the rapid drying, and the prevention of the spreading of the ink and of the unsealing of the package.

The value of the vacuum in steam disinfection lies in the fact that confined air in the chamber causes great delay in the attainment of the desired temperature and interferes much with the penetrating action of the steam. In Doty's experiments with and without the assistance of the vacuum, self-registering thermometers, placed within packages of newspapers, sheets, blankets, and rugs, showed differences ranging from nothing to a 100 degrees (F.) after 3 minutes' exposure, the higher temperature in each case being reached in the experiment with vacuum, and the smaller differences occurring when the articles were loosely wrapped. With longer exposure, the differences were considerably smaller.

When no appliance for securing a vacuum is a part of a steam disinfector, the contained air may be driven out through a vent controlled by a valve, which is opened for a time, while the steam is being admitted, and then closed.

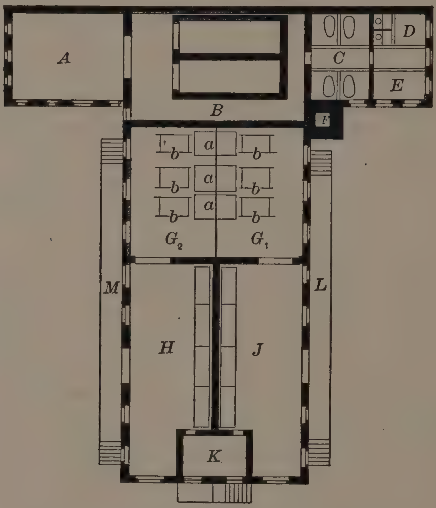
Another point in favor of the vacuum is the lessened opportunity for condensation of the steam in the interior of bundles and in the interstices of fabrics. It has been found to be advantageous to fill the chamber several times at short intervals with a fresh charge of steam, and when the vacuum appliance is at hand, the time required for this series of operations is lessened materially.

The penetrating power of steam is greatly dependent upon the amount of pressure; the lower the pressure, the less the penetration.

With machines in which low-pressure steam—a pound or two, for instance—is employed, penetration is, therefore, very slow and uncertain; and when bulky articles, such as rolled carpets and bedding, are treated, the results are likely to be unsatisfactory. For such articles, it is agreed generally that a pressure of at least 20 pounds is none too great. With whatever pressure employed, penetration may be much assisted by arranging the contents of the chamber so that too solid packing is avoided. This is secured by the interposition of wooden slats and gratings, which leave spaces between the different layers, through which the steam is distributed more readily.

With low-pressure steam, condensation is much more likely to be troublesome than when high pressures are employed; but ordinarily even then but little, if any, injury is suffered by the most delicate fabrics, beyond a slight impairment of gloss or the imparting of a slight yellowish tinge.

FIG. 91.



Ground plan of public disinfecting station.

In the arrangement of public disinfecting stations, it is essential that infected and disinfected articles shall be kept strictly apart, and that means shall be at hand for the proper treatment of articles not suited to disinfection by steam. As an example of simple, convenient, and efficient arrangement, may be cited the first public station installed in Berlin, the ground plan of which is shown in Fig. 91.[1] Here the infected articles are unloaded at the platform *L* and stored in the room *J*, from which they are carried into the room G_1, between which and the room G_2, the steam disinfectors are installed. They are loaded into the trucks *b*, *b*, *b*, which are pushed into the steam chambers *a*, *a*, *a*, the doors of which are then securely closed. Steam

[1] Taken from H. Merke's description in Vierteljahrsschrift für gerichtliche Medicin und öffentliches Sanitätswesen, XLV., p. 137.

is admitted from the boilers in room *B*, and after the proper interval of time, the doors of the chambers opening into the room G_2 are opened and the trucks withdrawn. The disinfected articles are removed and carried into the store-room *A*, from which they are sent to the platform *M* for shipment, in special wagons, back to their owners. *A* is a repair shop and store-room for coal, *C* and *D* are bath-rooms and water-closets for the attendants, and *E* is a store-room for chemicals. No communication whatever exists between the rooms in which the infected and disinfected articles are stored, nor between G_1 and G_2, except through the steam chambers, the doors of which are never opened at both ends at the same time. The work is directed by telephone from the office *K*, which is shut off completely from *H* and *J*, a full view of which is obtained through windows hermetically sealed.

Steam disinfectors are used extensively for purposes other than the destruction of disease germs; they are most useful for renovating bedding and in the treatment of clothing infested with lice, which with their eggs are killed quickly by steam at any pressure.

Boiling Water.—Articles not injuriously affected by boiling water may be disinfected most conveniently in the household by being boiled for a half hour. This suffices to kill all varieties of bacteria and the most resistant spores of pathogenic bacteria; in fact, all organisms excepting the spores of a number of non-pathogenic bacteria which are not destroyed even after prolonged boiling. This method is adapted particularly to bed-linen and body-linen and, in short, to all washable fabrics except woollens. It has the disadvantage of fixing stains, so that they become permanent; therefore, sheets, night-dresses, and other articles stained with blood or excreta, should have a preliminary soaking in cold water, so that the spots may be removed.

Cold.—Although cold is a very efficient antiseptic, but not commonly classed as a disinfectant, it appears to have destructive power over certain pathogenic bacteria, but none whatever over certain others, even when extremely low temperatures are employed. During the cholera epidemic in Germany, in the winter of 1892–93, Uffelmann,[1] experimenting with cholera germs, concluded that they have considerable power to withstand cold for periods varying with the temperature. Renk[2] placed the limit of endurance in ice at 8 days. Inoculated water, containing 620,000 per cc., was frozen at — 9.6° C. and kept at that temperature for 39 hours; the ice was then melted and tested, and the results were negative. Water more richly inoculated and kept for a day in a freezing-mixture of ice and salt yielded negative results. Still richer water, containing countless bacteria, was frozen, and after 48 hours yielded 24,400 per cc., and after 96 hours gave 12 negative results. In other experiments in which freezing was interrupted, no organisms were found after 6 and 7 days. But Wuknow[3] kept them alive more than a month at —32.5° C.

[1] Berliner klinische Wochenschrift, 1893, No. 7.
[2] Fortschritte der Medicin, May 15, 1893.
[3] Wratsch, 1893, No. 8.

The typhoid organism, as is well known, may survive the action of cold for a long time. This was well shown in the experience of Plymouth, Pa., where, in 1885, a most devastating epidemic occurred after the thawing out of an accumulation of typhoid excreta situated near a brook which supplied the town with drinking-water. (See page 380.) Prudden[1] has shown that the typhoid bacillus can withstand freezing temperatures for no less than 103 days, but that alternate freezing and thawing cannot long be withstood.

Non-sporulating anthrax bacilli have but little resistance to freezing temperatures, and are killed very quickly, but the spores have been found by Frankland, Pictet, and others to be not affected by repeated freezing and thawing. Meyer[2] found the spores to be unaffected by 15 minutes' exposure to the temperature of liquid air. Kasanskey[3] exposed 16 culture tubes of diphtheria bacilli to the winter's cold, so that for 4 months they were frozen continuously, the temperature at times falling to —25° C., and found after 6 months but 1 which contained living bacilli. Cultures of plague bacilli kept at —24° C. yielded living organisms at the end of 35 days, but none after 6 months; but cultures on agar exposed to lower temperatures were active at the end of nearly 6 months.

The exceedingly low temperature of liquid air, —312° F., appears to have no effect on organisms subjected to it for short periods. Ravenel[4] immersed silk threads, bearing anthrax spores, *B. prodigiosus*, *B. typhosus*, and *B. diphtheriæ*, in liquid air for varying periods, and then planted them in bouillon. Not only were the bacteria not killed, but their growth was in no way inhibited, multiplication being in every instance as rapid and vigorous as with the controls. The anthrax spores were exposed as long as 3 hours, but the diphtheria organism no longer than 30 minutes, and the other two forms not more than 1 hour.

Still more conclusive are the experiments of Macfadyen and Rowland,[5] who subjected broth emulsions of *B. typhosus*, *B. coli communis*, *B. diphtheriæ*, *B. proteus vulgaris*, *B. acidi lactici*, *Sp. choleræ Asiaticæ*, *Staphylococcus pyogenes aureus*, *B. anthracis* (sporulating), *B. phosphorescens*, a sarcina, a saccharomyces, and unsterilized milk, hermetically sealed in fine quills, to the refrigerating influence of liquid air for 7 days. At the end of this time, the quills were withdrawn and allowed to thaw. Culture experiments proved that the vitality of the various micro-organisms was in no way impaired. Every species grew well, the photogenic bacteria grew and emitted light, and the milk became curdled.

CHEMICAL AGENTS.

The list of substances falling under the head of chemical disinfectants is very long, and includes a wide variety of organic and inorganic compounds, some of which are gases, some liquids, and others soluble

[1] Medical Record, March 26, 1887.
[2] Centralblatt für Bakteriologie, XXVIII., p. 594.
[3] Ibidem, XXV., p. 122.
[4] Medical News, June 10, 1899.
[5] Lancet, April 21, 1900.

salts. While it is very long—for almost any chemical substance possesses under one condition or another a certain degree of bactericidal power—the number of agents which may be regarded as trustworthy in actual general practice is exceeding small. Many substances which have a high reputation for efficiency are found to be actually worthless when subjected to modern methods of testing, and others which yield promising results in the laboratory are found often to fail when used under the conditions which obtain in practice.

The undeserved reputation of many preparations is based wholly upon the apparent influence which they have exerted in limiting the spread of infectious diseases, and it has not been impaired by unexplainable failure to accomplish the same result at other times. An outbreak of an infectious disease occurs, for example, in a boarding-school, and during its continuance a number of bottles of some proprietary preparation are used; no further cases are reported, and the credit is given to the disinfectant. Six months later, perhaps, another outbreak occurs, and, in spite of the use of the same agent, it spreads and the school is closed; this result is not charged on the other side of the account, but to the inscrutable ways of Providence, and the fame of the disinfectant is in no way injured. In many instances, strength and peculiarity of odor are the only qualities necessary for the building up of a reputation for efficiency, for man is wont to attribute potent properties to unusual things.

Many substances have undoubted germicidal power over certain forms of bacteria, and are quite inert against others; some will kill every known form under some conditions, and yet may wholly fail to affect bacteria of slight resisting power protected by mucus or other matter, or may even be rendered inert almost immediately by chemical union with some other substance accidentally present.

Chemical disinfectants act in various ways to bring about the destruction of bacteria. Some act directly upon the bacterial protoplasm and cause its coagulation; some bring about changes in reaction favorable to life and growth; some destroy nutritive material by chemical change; some take up all the available oxygen, thus becoming themselves changed in character while depriving the bacteria of an essential element; and others bring in such an excess of this same element that the bacteria cannot withstand its action. Some even stimulate multiplication, and thus act only indirectly by promoting the formation of organic compounds which exert a destructive influence upon the organisms by which they have been produced. The disinfectant power of many of the metallic salts depends partly upon the nature of the solvent.

Different agents produce their best results in different degrees of concentration; thus, while one may be efficient in 5 per cent. solution, another may act equally well or better in 0.10 per cent. or even weaker solution. Some agents, as, for instance, alcohol, are most bactericidal at some one point of concentration, and above and below this the property progressively diminishes. In applying any agent whose best work-

ing strength is known, it should be borne in mind that it is not sufficient to use a small volume of solution of that particular strength, but that the substance itself must be employed in such an amount that it shall be present throughout the whole mass in the proportion required. Thus, an agent which is effective in 2 per cent. solution cannot be used in that strength to disinfect an equal bulk of infective material, since the mixture would then contain but 1 per cent.

Non-metallic Elements and Their Compounds.

Oxygen.—The disinfectant property of pure air is due to its oxygen, which attacks organic matter under favorable conditions and converts it in great part to carbon dioxide and water. Prolonged aëration is rightly regarded as a valuable assistant in disinfection, but it should not be overlooked that when infected objects are exposed to moving currents of outdoor air, they are subjected also to the powerful influence of the chemical rays of sunlight and to the possibility of desiccation. Oxygen acts most powerfully in the nascent state, as when liberated from compounds whose decomposition results in the escape of the gas in the free condition. Among these compounds, ozone, the allotropic form of oxygen, containing in each molecule three atoms instead of two, and hydrogen peroxide, may be mentioned as conspicuous examples of oxidizing agents which part very readily with the loosely held element.

Ozone, in the minute amounts in which it exists normally in air, can hardly be regarded as an important influence in practical disinfection. Produced artificially by means of the silent electric discharge, it is found to be possessed of marked bactericidal power, and has been recommended highly for special work, particularly in the sterilization of drinking-water. The researches of a number of investigators have demonstrated that dry bacteria are not much affected by dry ozone, but that in a moist condition they are quickly destroyed by small amounts.

Krukowitsch, quoted by Kowalkowsky,[1] experimenting, in 1882, with putrefactive bacteria, found that 3 milligrams of ozone per cubic meter of air killed fresh bacteria, exposed on paper, within an hour, and 8 milligrams per cubic meter sufficed to destroy the dried organisms. Later (1888), Lukaschewitsch, experimenting with *B. subtilis*, *B. anthracis*, *Sp. choleræ Asiaticæ*, and certain putrefactive bacteria, obtained results which were less favorable, but in agreement in so far as they demonstrated the relatively slower action exerted on dry bacteria. Spores of *B. subtilis* and *B. anthracis* in a dry state were unaffected by 1.50 grams of ozone per cubic meter, and the comma bacillus, in a moist condition, was not affected until after 15 hours' exposure to the same atmosphere.

Ohlmüller[2] employed a much greater strength, namely, 15 grams

[1] Zeitschrift für Hygiene, IX., p. 89.
[2] Arbeiten aus dem kaiserlichen Gesundheitsamte, VIII., 1892, p. 229.

to the cubic meter, and conducted the air through distilled water, in which bacteria were suspended. Water containing anthrax spores was sterilized in 10 minutes by 89.9 milligrams of ozone; and containing millions of typhoid and cholera germs to the cubic centimeter, in 2 minutes by less than 20 milligrams. River-water and sewage were found to be much less affected, but with only moderate pollution it appeared probable that in ozone might be found a cheap and efficient means of purifying drinking-water. Later on, a number of processes were devised for this purpose and carried out on a large scale.

In the hope of arriving at some definite conclusion as to the availability of ozone as a room disinfectant, Ransome and Foulerton[1] conducted a series of experiments in which large quantities were used, mixed with air or with pure oxygen. The organisms employed as tests included *B. tuberculosis*, *B. mallei*, *B. diphtheriæ*, *B. anthracis* (sporing), *B. typhosus*, *B. coli communis*, *B. pyocyaneus*, *B. pneumoniæ* (Friedländer), *B. prodigiosus*, *Staph. pyogenes aureus*, *Strep. pyogenes*, *Micr. candicans*, *Saccharomyces albicans*, *Sarcina ventriculi*, and an anaërobic, sporing, butyric-acid-forming bacillus. The results demonstrated that dry ozone has no appreciable action on the vitality of these organisms; that prolonged exposure does not diminish the pathogenic virulence of *B. tuberculosis* in sputum, *B. mallei* or *B. anthracis*; that ozone passed through a fluid medium containing bacteria has germicidal power: "that any purifying action which ozone may have in the economy of nature is due to the direct chemical oxidation of putrescible matter; and that it does not in any way hinder the action of bacteria, which latter are, indeed, in their own way, working toward the same end as the ozone itself in resolving dead organic matter to simpler non-putrescible substances."

Hydrogen peroxide, H_2O_2, is quite stable in the presence of some substances, but gives up its loosely combined atom of oxygen very readily to others. It is a powerful, odorless oxidizing agent, prepared by the action of dilute sulphuric acid on barium peroxide. It is destructive of bacteria, but has no action on the enzymes of the digestive juices, and in dilute form is neither poisonous nor irritant in the human system.

According to Altehöfer,[2] in the proportion of 1 part in 1,000 of water containing the organisms of cholera and typhoid fever, it produces sterility within 24 hours. In 1 per cent. solution, according to Traugott,[3] the bacilli of diphtheria and typhoid fever are killed in 5 minutes, the organisms of erysipelas and cholera in 2 minutes, *Streptococcus pyogenes* in 10 minutes, and *Staphylococcus pyogenes aureus* in from 15 to 30 minutes. With half this strength, the typhoid organism and *Streptococcus pyogenes* are destroyed with equal promptness, the cholera and erysipelas organisms in 5 minutes, the bacillus of diphtheria in 15, and *Staphylococcus pyogenes aureus* in an hour. It is believed by many that the bactericidal effect of sunlight on organisms

[1] Public Health, July, 1901, p. 684.
[2] Centralblatt für Bakteriologie, VIII., p. 129.
[3] Zeitschrift für Hygiene und Infectionskrankheiten, XIV., p. 427.

in surface-waters is due to the hydrogen peroxide produced through its influence.

Chlorine, both in the free gaseous condition and in solution in water, has very powerful disinfectant and deodorant properties. It decomposes the offensive gaseous products of putrefaction, such as ammonia and sulphuretted hydrogen, and in the presence of moisture unites with hydrogen, thus liberating oxygen in the nascent state, which is enabled thereby to exert its power against organic matter. In the dry state, its disinfectant action on dry matter is but slight and unreliable; but in the presence of a moderate degree of atmospheric moisture, its effect on organic matter is considerable, as is shown by its bleaching action on dyed fabrics. The exhaustive research of Fischer and Proskauer[1] demonstrated, however, that chlorine as a fumigating agent is untrustworthy, and that its application is attended by serious disadvantages. The test-objects employed embraced a somewhat wide variety of pathogenic and non-pathogenic organisms, and were exposed under different conditions of moisture and dryness for varying periods and to different percentages of the gas. The results, as a whole, were highly unsatisfactory from a practical standpoint, on account of the impossibility of properly regulating all the necessary conditions, the absence of penetrating power, the destructive action on fabrics and other articles, and the uncertainty in achieving the object sought.

"**Chloride of Lime**," which is a combination of calcium chloride and hypochlorite, the result of passing chlorine over dry slaked lime, was in use as a disinfectant and deodorant for a long time before the development of the science of bacteriology. In 1881, in the course of the first real investigation of the properties of what were commonly regarded as disinfectants, Koch obtained very unsatisfactory results from his tests with this agent, which thereupon to a great extent was discarded. In 1885, Sternberg, then chairman of the committee of the American Public Health Association to which, in 1884, the subject of disinfectants had been referred, took very different ground regarding this and other hypochlorites, and asserted their efficiency in no uncertain terms. Since then, the matter has been the subject of many investigations by competent observers, and while in some hands the results have failed to be uniformly favorable, the work, as a whole, has sustained the position taken by Sternberg as a result of his own experiments.

Woronzoff, Winogradoff, and Kolesnikoff[2] demonstrated that anthrax spores were killed in 1 minute by a 5 per cent. solution, although in Koch's experiments they had been found still active at the expiration of 2 days. Jaeger,[3] in 1889, concluded, after a series of tests with a number of species of pathogenic bacteria, that it is a very efficient disinfectant, even in weak solutions. Nissen,[4] in 1890, after

[1] Mittheilungen aus dem kaiserlichen Gesundheitsamte, II., p. 228.
[2] Centralblatt für Bakteriologie, 1887, p. 641.
[3] Arbeiten aus dem kaiserlichen Gesundheitsamte, V., p. 247.
[4] Zeitschrift für Hygiene, VIII., p. 62.

a series of careful experiments, reported that the organisms of cholera and typhoid fever were destroyed in 5 minutes when the material in which they were present contained 0.12 per cent. of the agent, and in 10 minutes by half that amount. Anthrax bacilli were killed in 1 minute by 0.10 per cent.; *Staphylococcus pyogenes aureus* and *Streptococcus erysipelatis* in 5 minutes by 0.12 and 0.15 per cent., respectively, and in 1 minute by 0.20. Anthrax spores of low resistance were destroyed in 15 minutes by 5 per cent. and in 70 minutes by 1 per cent. Very resistant spores, capable of surviving 4 hours' immersion in 0.10 per cent. corrosive sublimate and 10 minutes' exposure to streaming steam, were killed in 4.5 hours by 5 per cent.

Klein,[1] experimenting with sodium hypochlorite in 10 per cent. solution (1.0 per cent. chlorine) on the colon bacillus, anthrax spores, *Staphylococcus pyogenes aureus*, *B. enteritidis sporogenes*, and the bacteria of typhoid fever, cholera, and swine fever, found that all were killed in 20 minutes, and the non-spore-bearers in 10. In one-tenth as strong solution, all but the two kinds of spores were destroyed within 20 minutes. Duggan,[2] working according to Sternberg's method, reported, in 1885, that his experiments had shown "that a solution containing 0.25 per cent. of chlorine as hypochlorite is an effective germicide, even when allowed to act for only 1 or 2 minutes, while 0.06 per cent. will kill spores of *B. anthracis* and *B. subtilis* in 2 hours."

The composition of "chloride of lime," or, more properly, *chlorinated lime*, and its mode of action, are matters concerning which there is considerable disagreement. The substance is held variously to be: (1) a mixture of calcium chloride and hypochlorite; (2) calcium hypochlorite in which one ClO is replaced by Cl, that is, Ca(ClO)Cl, which, in contact with water, is broken up into calcium chloride and hypochlorite; (3) a compound of calcium hypochlorite and oxychloride with $4H_2O$, formed according to the equation

$$4CaO_2H_2 + 2Cl_2 = CaO_2Cl_2.\ Ca_3O_2Cl_2 4H_2O,$$

which is split up in water into calcium chloride, hypochlorite, and hydroxide; and (4) a compound of calcium chloride with hydroxide, of which one H is replaced by Cl. It is white or whitish in color, and occurs as a powder or as friable lumps; it should be dry or nearly so, and should have no more than a faint odor of chlorine, which element should be present in available form to the extent of not less than 35 per cent. to conform to the requirements of the U. S. P. (British standard = 33 per cent., German standard = 25 per cent.).

With keeping, under various conditions, chlorinated lime may undergo decomposition in a number of ways. A pasty condition or a strong odor of chlorine is evidence of partial decomposition. It is only partially soluble in water, and its aqueous preparations are made best by triturating the requisite amount with water to the consistency of cream,

[1] The Lancet, Nov. 26, 1896, p. 509.

[2] Report of the Committee on Disinfectants of the American Public Health Association: Baltimore, 1885, p. 12.

and then diluting to the desired volume. The addition of acids to the solution causes evolution of chlorine, but the carbon dioxide naturally present in the water or absorbed from the air decomposes the hypochlorite, yielding calcium carbonate and hypochlorous acid, the latter of which breaks up into active oxygen and free hydrochloric acid.

The solution known as the "American standard" contains 6 ounces of the powder to the gallon. It is used largely in the disinfection of discharges, and for scrubbing floors and other woodwork. A weaker solution is employed for the treatment of infected bed-linen and washable clothing, but on account of its destructive action, these articles should, after a not too long immersion, be washed thoroughly in plenty of fresh water.

Sodium hypochlorite solution, otherwise known as chlorinated soda, Labarraque's solution, and liquor sodæ chloratæ, is "an aqueous solution of several chlorine compounds of sodium, chiefly $NaClO$ and $NaCl$, and containing at least 2.6 per cent. by weight of available chlorine" (U. S. P.). It is used, but not so extensively, for the same purposes as chlorinated lime.

Bromide and **Iodine** have powerful disinfectant properties, but for several reasons are not suited to the purposes of practical disinfection. In some respects, bromine is superior to chlorine as a germicide, but it is disagreeable and dangerous to handle, and is much more expensive. Iodine is less efficient than chlorine, and offers, neither as such nor as the trichloride, any advantage over chlorine and the hypochlorites, but, on the contrary, a number of disadvantages which are sufficient to eliminate it from the list of practical disinfectants.

Sulphur dioxide easily outranks all other disinfectants in point of length of service, its use dating back to very ancient times. While it has undoubted bactericidal properties, it has been demonstrated by Koch, Wolffhügel, and their associates, and many others, to be wholly untrustworthy for general use, and although still very extensively employed by public sanitary authorities, is rapidly being abandoned in favor of more efficient and reliable agents. It is purely a surface disinfectant under conditions most favorable to its action, and even then is effective against only a somewhat limited number of species of pathogenic bacteria. It is, however, very efficient against mosquitoes.

Sulphur dioxide is a colorless irrespirable gas, produced by burning roll sulphur or "flowers" in an iron vessel, placed as a precaution against fire in a pan of water, or by burning sulphur candles or carbon disulphide, the latter in a lamp. The amount of sulphur employed varies, according to the custom of the operator, from 1 to 6 pounds per 1,000 cubic feet of air space; but the whole amount is never consumed, and, indeed, under ordinary circumstances, combustion ceases before a half or even a third has been burned. In order to avoid the necessity of burning sulphur, the liquefied gas, contained in cylinders, is employed to some extent.

In the absence of moisture, the action of sulphur dioxide on even the least resistant bacteria is practically *nil*, and even when water is

evaporated in the room beforehand or at the same time, and the gas is present in the highest percentage possible, the exposed organisms, whether of low or high resistance, are likely to retain their vitality unimpaired. It is true that some experimenters have reported great success in the destruction of pathogenic organisms by means of this agent, but the adverse reports are so numerous that it must be clear that much official disinfection by means of it is worse than an empty form and, by reason of causing a false sense of security, a positive danger. Even were it an efficient disinfectant, the many disadvantages which attend its use would suffice to make it undesirable for general purposes, especially in view of the fact that the same disadvantages are wholly absent in other processes. In the presence of moisture and air, it is to some extent oxidized to sulphuric acid, which corrodes fabrics and other objects; it reduces organic matters and destroys organic colors; it tarnishes brass and silver ware, gilt frames, and other objects; it leaves a disagreeable odor which persists for days and even weeks after thorough aëration; bedding and other articles become impregnated with a peculiar highly offensive odor which renders their use unpleasant and even impossible; and it has such little power of penetration that only such organisms as are exposed openly are likely to be affected.

Where sulphur dioxide is the official disinfectant, it is commonly enjoined that the room shall be cleansed thoroughly and air freely admitted for some days after fumigation. The necessity of this supplementary process is in itself an admission of the inadequacy of the main operation, for if sulphur is an efficient disinfectant, the application of soft soap, carbolic acid, hypochlorites, and other agents by means of the scrubbing-brush and cloths, the removal and replacing of wall-papers, the process of white-washing, and other means of renovation recommended, are attacks against an imaginary evil. Granted that these processes are necessary, the claims of sulphur dioxide as a practical disinfectant must fall to the ground; if not necessary, they should not be enjoined.

Lime and Metallic Salts.

Lime, quicklime, or calcium oxide, has long been known as an agent possessing great power in destroying organic matter, and has been used extensively from very early times in connection with disposal of the dead. Treated with half its weight of water, it is slaked to a dry powder, the hydrate, which, mixed with sufficient water, forms the well-known "white wash" commonly used for disinfecting, sweetening, and brightening the walls of cellars, rooms, barracks, barns, poultry-houses, and other outbuildings. Slaked lime, mixed with four volumes of water to the consistency of cream, forms what is commonly known as "milk of lime," which is used extensively in the disinfection of excreta and privy vaults.

The scientific investigation of the disinfectant properties of lime by

Liborius,[1] undertaken at the instance of Koch, demonstrated its value in the destruction of the bacteria of typhoid fever and cholera, the former of which were found to be destroyed in a few hours by lime-water containing 0.0074 per cent., and the latter within the same time by 0.0246 per cent. Cholera bouillon cultures, containing numerous coagula of albumin, such as would be present in cholera discharges, thus offering unfavorable conditions for the action of the disinfectant, were completely disinfected within the course of a few hours by 0.40 per cent. of pure lime or by 2 per cent. of ordinary crude lime. He recommended the employment of the pure dry powder or of milk of lime containing 20 per cent. thereof.

Favorable results were obtained also by Kitasato,[2] who found that the same two species were destroyed by about 0.10 per cent. in from four to five hours. Pfuhl,[3] carrying the experiments somewhat farther, recommended the use of milk of lime of 20 per cent. strength, freshly prepared from lime of good quality, for the disinfection of loose dejections, prescribing that it should be added in sufficient quantity, with thorough mixing, until the whole mass is strongly alkaline in every part, as shown by testing with red litmus-paper. With such treatment, he asserted that complete sterilization is accomplished within an hour. Extensive researches by numerous other scientists, although differing somewhat in results in certain unimportant particulars, have confirmed the conclusions of these earlier investigators as to the great practical value of this agent. As to its value in comparison with chlorinated lime, there is disagreement, some authorities favoring the one and some the other, but practically all unite in the opinion that, whichever is the more efficient, the difference is slight.

Of great practical importance in the use of any disinfectant on a large scale is the item of expense. It happens, fortunately, that this valuable aid is exceedingly cheap, and that its use with a liberal hand in excess of the recommended amount may be urged without promoting lavish expenditure of money. In the disinfection of stools it is commonly advised to add at least an equal volume of the milk, or even twice as much, and to allow the mixture to stand for two hours or longer before final disposal. In camp sanitation, it is much used with excellent results; but for their attainment, constant watchful supervision is necessary.

It should be borne in mind that air-slaked lime should not be employed in the preparation of the milk, and that the latter on standing loses its homogeneous character, which should be restored by stirring or shaking each time the material is used. The milk is most powerful when freshly prepared, and should not be used when older than a few days, unless most carefully protected from contact with air.

Ferrous sulphate and other salts of iron have long been used extensively both as germicides and deodorants. All scientific investi-

[1] Zeitschrift für Hygiene, II., p. 15.
[2] Ibidem, III., p. 404.
[3] Ibidem, VI., p. 97.

gations of the disinfectant properties of ferrous sulphate by Koch, Sternberg, and others have demonstrated the utter worthlessness of this agent. Not only does it fail as a germicide, but, as has been pointed out by Foote,[1] it has also no claim to be considered as a deodorant. Its employment in this capacity not infrequently makes a bad odor worse, through chemical action on organic compounds produced in the process of putrefaction.

Ferric sulphate has been shown by Riecke[2] to have very marked action against the bacteria of typhoid fever and cholera in acid and alkaline excreta, when added in an equal volume of 5 per cent. solution. The disadvantages attending its use, however, more than outweigh any considerations which may be urged in favor of its employment in place of other more efficient and, on all accounts, less objectionable agents.

Ferric chloride, also, has some claim to be regarded as a germicide, but it is inferior to the sulphate and is open to the same objections.

On the whole, therefore, the iron compounds may safely be passed by in the practice of disinfection.

Zinc chloride, like ferrous sulphate, was, until subjected to the rigid test of bacteriological proof, regarded as a most efficient disinfectant, and to-day, although the original adverse findings of Koch, in 1881, have been confirmed by many careful experimenters, it is still very extensively employed, and in many places is prescribed officially by the local health authorities. Under some conditions, it does succeed occasionally in destroying some forms of bacterial life, but its place in the list of actual and supposed disinfectants is well down toward the very bottom. It is, however, somewhat efficient as a deodorant. The sulphate and other salts are equally inefficient as disinfectants.

Aluminum chloride is the chief soluble constituent of a number of extremely popular proprietary disinfectants, prescribed by practising physicians and bought with and without advice by the laity. Like other aluminum compounds, the sulphate and the alums, for example, it is powerfully astringent, even in dilute form. It is cheap, has no action on metallic substances, and does not stain nor otherwise injure fabrics. Its disinfectant action is slight, and herein it agrees farther with other aluminum compounds. A number of proprietary preparations, in which it is present either as principal or auxiliary ingredient, examined by the author with Dr. R. M. Pearce,[3] were found to be inefficient. The test-objects included cultures of *B. anthracis* and *B. typhosus*, typhoid dejecta, diphtheritic membranes, and tuberculous sputa. Each of five preparations, in the strength recommended, was subjected to 10 tests, and their proportions of successful disinfection varied from 20 to 70 per cent. Anthrax bacilli were destroyed by one; one culture of *B. typhosus* was killed by one, another by all, a third by two; one typhoid stool was unaffected by all, a second was

[1] American Journal of the Medical Sciences, XCVIII., p. 329.
[2] Zeitschrift für Hygiene und Infectionskrankheiten, XXIV., p. 303.
[3] Journal of the Boston Society of Medical Sciences, March, 1899.

sterilized by all, and a third by three; one specimen of diphtheritic membrane was sterilized by four, and another by only one; tuberculous sputum was affected by none.

Potassium permanganate, well known as a powerful oxidizing agent, is much used in surgical practice and in other lines of special work. In the process of sterilization of the hands, however, it is incapable, as the author has shown,[1] of producing the results for which it is employed. In contact with organic matter and oxidizable mineral substances, it parts very readily with its available oxygen, and it is to this element that whatever disinfectant property it has, is due. It cannot be used in the treatment of excreta, because of the very large amount which would be required to produce complete sterility of even a single ounce of fæces; nor can it be employed in the treatment of clothing, because of the permanent stains which it produces.

Copper sulphate in weak solutions destroys sporeless bacteria in great variety within a short time, but in practical work its use is rather limited. Although it appears to be of considerable value in the destruction of certain forms of algal growth in public water supplies, the assertions made concerning its germicidal value in the treatment of infected waters have not as yet been substantiated, and in the light of a number of recent investigations it would seem probable that they must fall to the ground. It has been recommended strongly for the sterilization of fæces, but its cost and other disadvantages, not to mention its inferiority as a germicide to other cheaper and more available substances, make it improbable that its employment will ever become very extensive.

Mercuric chloride or **corrosive sublimate** is, beyond question, the most powerful of all the metallic salts as a disinfectant, but at the same time it enjoys a reputation for practical efficiency that is not wholly deserved. A number of the earlier experiments which gave it its standing led to conclusions which could not be justified by later work conducted on lines of greater accuracy and with improved technic; but while Koch and others saw fit to modify their original estimate of its general efficiency, it would appear that a large proportion of those who have occasion to employ germicides are influenced more by the original than by the later investigations. In testing its disinfection properties against anthrax spores and other highly resistant organisms, widely different results have been obtained and recorded by different observers, but these are explained by differences in nutrient media, in technic, and in virulence; and although it has been proved that the original findings were far too favorable, it also has been proved that as a germicide it stands far above all other metallic compounds. But it should be understood that, under conditions which obtain in practice, the same results as are obtained in laboratory experiments, made with broth cultures and spores dried on silk threads, are not always to be expected. In the treatment of tuberculous sputum,

[1] Annals of Surgery, October, 1904.

for example, the innermost bacilli are protected from contact with the disinfectant by the coagulum which forms on the surface of each separate mass. Again, in the treatment of other organic matter, the possibility of precipitation as albuminate or sulphide or other insoluble compound of mercury should be kept in mind.

Precipitation as albuminate may be prevented by the addition of about 5 parts of sulphuric, hydrochloric, or tartaric acid, or of 10 parts of common salt, for each part of sublimate in 1,000, but conversion to sulphide cannot be prevented, if the conditions necessary for its formation are present. In the disinfection of fæces, for which purpose corrosive sublimate is sometimes used, it is evident that, with the usual strength of solution employed, the whole of the salt must frequently be precipitated in one form or another very early in the process. In household disinfection, its corrosive action on plumbing must be considered as a serious drawback.

Its chief use in surgical practice is as a sterilizing agent for the skin, ligatures, etc., the strength used being commonly 1 part in 1000; but weaker solutions, even 1 in 10,000, are also employed. Unfortunately the element of time seems not to be generally regarded in the practice of disinfection, and instantaneous germicidal action appears to be assumed as the result of contact of the agent with pathogenic bacteria. In order to determine the length of time required for solutions of different strengths to destroy some of the commoner pathogenic organisms, the author[1] conducted, with Dr. Harold Walker, a series of experiments which led to the following conclusions:

(1) Different species of pathogenic bacteria, and different cultures of the same species, vary very greatly in their resistance to the action of corrosive sublimate. (2) With some species resistance is diminished in a remarkable degree by a condition of dryness, so that even the 1 : 10,000 solution can bring about sterility in a very short time. But some species are not materially affected in this respect by dryness. (3) Corrosive sublimate in as weak solution as 1 : 5000 is ineffective against the common pathogenic bacteria, including the pus organisms when they are moist, excepting after prolonged contact. Since fifteen minutes' contact is not sufficient for the destruction of *B. coli communis*, *B. pyocyaneus*, and *Staph. pyogenes albus*, in the moist state, or of *Staph. pyogenes aureus* whether moist or dry, the use of this and of weaker preparations in surgical work and for irrigation and similar purposes should be abandoned. (4) The 1 : 1000 solution is very slow in its action on some of the commonest of the skin bacteria, and since under the most favorable conditions more than ten minutes' contact may be necessary for it to kill *Staphylococcus pyogenes albus*, it should not be relied upon to any great extent to ensure sterility of the hands or of instruments. The mere dipping of the hands for a few seconds into solutions of this strength can serve no useful purpose, but, on the contrary, can lead to much harm by inducing a false sense of security. (5) Corrosive sublimate in any of the strengths commonly employed is a much over-

[1] Boston Medical and Surgical Journal, April 23, 1903.

rated disinfectant, and, under the best of conditions, is so uncertain in its action that it would be of advantage to abandon its use altogether in surgery.

Mercuric cyanide, much praised by some, has been proved by the author[1] to be far inferior to the chloride.

Mineral Acids.

The mineral acids possess, in different degrees of dilution, varying disinfectant power against all species of bacteria. In any effective working strength, they corrode the common metals and destroy the tensile strength of all kinds of fabrics.

The bactericidal effect of gastric juice on the bacteria of cholera, discovered by Koch, was ascribed by him to the contained hydrochloric acid; and experimenting with bouillon cultures of this organism, Kitasato[2] showed that 0.132 per cent. of hydrochloric or 0.049 of sulphuric acid produced sterility within a few hours. This result, so far as it concerns sulphuric acid, was confirmed by Stutzer,[3] who found that 0.05 per cent. killed in 15 minutes the organisms suspended in distilled water.

The experiments of Boer[4] showed that the bacillus of typhoid fever in bouillon cultures was destroyed in 2 hours by 0.07 per cent. of hydrochloric acid, and in the same time by 0.12 per cent. of sulphuric acid. The cholera organism was killed by smaller amounts, 0.02 per cent. of each, within the same time; the bacilli of anthrax were but slightly more resistant than the cholera germ; and those of diphtheria succumbed to the same amounts as were fatal to those of typhoid fever. Ivanoff[5] determined the amount of sulphuric acid necessary to sterilize sewage. That of Potsdam, three times as foul as that of Berlin and slightly alkaline in reaction, impregnated with cholera germs, was disinfected by 0.08 per cent. in 15 minutes. A proprietary preparation, containing 0.76 per cent. of sulphuric acid and nothing else, tested by the author, sterilized one of two bouillon cultures of typhoid bacilli and one of two typhoid dejecta in 2 hours, but had no effect whatever on diphtheritic membrane and tuberculous sputum.

Organic Substances.

Carbolic acid, phenol, phenic acid, obtained chiefly from coal, is a substance of varying degrees of purity and disinfectant power. The highest grade is practically pure phenol, but the commoner qualities contain variable amounts of cresols, xylol, and other higher homologues, all of which have marked bactericidal properties, and tar oils which have none. In the opinion of many authorities, the crude acid

[1] Boston Medical and Surgical Journal, January 14, 1904.
[2] Zeitschrift für Hygiene, III., 1888, p. 404.
[3] Ibidem, XIV., 1893, p. 9.
[4] Ibidem, IX., 1890, p. 479.
[5] Ibidem, XV., 1893, p. 86.

is superior to the highest grades in disinfecting power by reason of the presence of the cresols.

Prior to Koch's work on disinfectants in 1881, carbolic acid was believed generally to be one of the most powerful of germicides, a belief which was due doubtless, in part at least, to its peculiar and powerful odor. Koch's experiments with anthrax spores led him to the conclusion that, even in 5 per cent. solution, it was an inefficient agent against highly resistant organisms. Then followed a number of investigations by others, whose conclusions were by no means in agreement. It was found by some to be a very efficient general disinfectant, by others to be very unreliable, and by still others to be well suited to some lines of work and not to others. It was conceded very generally that in certain respects its use has many advantages over that of corrosive sublimate and other metallic salts; that it is not destroyed or precipitated by contact with albumin, acids, salts, and other compounds; and that, even in weak dilution, it destroys many of the common pathogenic organisms very quickly.

Behring, Sternberg, and others found it effective against the bacilli of typhoid fever and cholera in 1 per cent. solution, but opposite conclusions have been reported as to its action against the former, which organism is said to flourish in mixed cultures in the presence of even as much as 5 per cent., the accompanying species being destroyed. According to Vincent,[1] the colon bacillus is killed only by solutions containing at least 3 per cent. For the disinfection of tuberculous sputum, Schill and Fischer[2] found it to be reliable in 5 per cent. solution within 24 hours. An experiment by the author and Dr. R. M. Pearce,[3] in which this material was treated with 17 different preparations, proprietary and otherwise, including a 5 per cent. solution of carbolic acid, was successful with this agent and 4 others after a 2 hours' exposure. With typhoid stools, diphtheritic membrane, and bouillon cultures of the typhoid organism, disinfection was not accomplished. Uffelmann[4] has reported that, while the 5 per cent. solution did not destroy the typhoid organism in an hour, sterilization was complete after 24 hours' exposure.

Its disinfectant power appears to be increased by heat and by the presence of mineral acids and common salt. Thus, Heider[5] found that, while at ordinary room temperature a 5 per cent. solution was ineffective against anthrax spores under 36 days, at 55° C. it was successful in 2 hours, and at 75° C. in 3 minutes. The influence of its association with common salt, which alone in ordinary amounts has but slight bactericidal power, is attested by Scheurlen, Beckmann, Römer, and others.

Scheurlen[6] demonstrated that, while 1 per cent. solutions had no effect against pus cocci during 5 minutes' exposure, the addition of

[1] Annales de l'Institut Pasteur, IX., 1895, p. 23.
[2] Mittheilungen aus dem kaiserlichen Gesundheitsamte, II., 1884, p. 145.
[3] Loco citato. [4] Deutsche medicinische Wochenschrift, XVI., 1890, p. 37.
[5] Centralblatt für Bakteriologie, IX., 1891, p. 221.
[6] Archiv für experimentale Pathologie, etc., XXXVII., 1896, p. 74.

common salt in considerable amounts brought about sterility in 1 minute, and that the same agent enhanced its action materially against anthrax spores. Beckmann[1] showed that, although 3 per cent. of salt increased the general disinfectant power of a 1 per cent. solution very considerably, no increase in its power against anthrax spores was observable until 24 per cent. had been added; but in this amount, salt itself has considerable power, and it would seem reasonable to attribute the effect of the mixture very largely, if not wholly, to it. Römer[2] also proved the same thing with respect to the action of a stronger solution (3 per cent.), which, with the addition of 8 per cent. of salt, was much more effective against the same organism.

Similarly, it has been shown by Fränkel and Laplace that the presence of small amounts of the mineral acids is very helpful, but it is to be borne in mind that the latter, unassisted, are by no means without a very considerable degree of germicidal power. Both authorities, however, have proved that mixtures of carbolic and mineral acids are more bactericidal than either ingredient in the proportions used, and both, and Nocht as well, have demonstrated also the superiority of mixtures of the crude acid with mineral acids over combinations of the pure phenol with mineral acids in the same proportions. According to Epstein,[3] carbolic acid in alcoholic solution is more powerful in the same amount than in aqueous solution, which finding is endorsed by Minervini.[4] On the other hand, in solution in oil, according to Koch, it loses its germicidal property completely.

On all the evidence presented, the conclusion must be drawn that carbolic acid, while effective in weak and saturated aqueous solution against many of the pathogenic bacteria, is not suited to the purposes of practical general disinfection. When used, it is best to employ the stronger rather than the dilute solutions. The pure acid is soluble in about 11 parts of water, but the commercially pure article is soluble in about 20 parts, giving about 5 per cent. strength.

The so-called carbolic powders are, as a rule, inert mixtures of mineral matter and waste products of coal-tar distillation. Their strong odor appeals to the imagination and promotes their sale.

The **cresols**, meta-cresol, ortho-cresol, and para-cresol, which occur as impurities of carbolic acid, and, according to many authorities, are more powerful as germicides and less poisonous to higher organisms, are constituents of a large number of preparations which, within recent years, have come into extensive use. The cresols are closely related to phenol, from which they differ in that CH_3 replaces one H in the benzol ring, and according to the position of CH_3, we have meta-cresol, ortho-cresol, or para-cresol. The latter may be made synthetically from pure para-toluidin. Cresols are practically insoluble in water, but solution is brought about by soaps and by cresol salts.

[1] Centralblatt für Bakteriologie, 1896, Nos. 16 and 17.
[2] Münchener medicinische Wochenschrift, XLV., 1898, p. 298.
[3] Zeitschrift für Hygiene und Infectionskrankheiten, XXIV., 1897, p. 1.
[4] Ibidem, XXIX., 1898, p. 117.

Laplace[1] was the first to draw attention to the fact that crude carbolic acid and strong sulphuric acid, mixed together, form a compound soluble in water and of high disinfectant power. He reported that the mixture in 4 per cent. solution destroyed anthrax spores within 24 hours, while pure carbolic acid in 2 per cent. solution had no effect whatever. The first extensive study of the action of cresol was made by Fränkel,[2] who showed that the mixture of sulphuric acid and crude cresols is not of the nature of a new compound, but that each ingredient exists by itself and exerts its own action, and that the acid keeps the cresols in solution. Hammer[3] investigated the properties of cresols dissolved in sodium meta-cresotinate; here, also, no double compound is formed, the salt acting merely as a solvent. Sodium salicylate acts equally well as a solvent. The various preparations containing cresols and solvents of the same are recommended highly as substitutes for phenol, on the ground of higher bactericidal power, lower toxicity, and of being less irritating in surgical work. They may be diluted at will with water, some forming milky emulsions, some clear solutions.

To determine the toxic properties of the cresols, Seybold[4] instituted a series of experiments with guinea-pigs, into which 2 per cent. solutions of the individual cresols were injected subcutaneously. The most poisonous was found to be para-cresol, and the least so proved to be meta-cresol, which is also much less poisonous than phenol. From a study of the comparative disinfectant action of the several cresols and of several other preparations, including tri-cresol (prepared synthetically from toluene) and phenol, he concluded that of the three isomers, meta-cresol is the most powerful, and that the cresols are all superior to phenol. Tri-cresol, which is 40 per cent. meta-, 35 per cent. ortho-, and 25 per cent. para-cresol, proved to have double the bactericidal power of phenol against *B. pyocyaneus*, *B. prodigiosus*, and *Staphylococcus pyogenes aureus*. Another preparation of cresol, made by another manufacturer and examined by Schürmayer,[5] also proved to be far superior to phenol and to a number of the more commonly known cresol compounds. A proprietary preparation of cresols, examined by the author,[6] sterilized in 5 per cent. dilution in 2 hours, cultures of *B. typhosus*, typhoid dejecta, diphtheritic membrane, and tuberculous sputum.

Among the more commonly used cresol preparations may be mentioned the following:

Creolin.—This is a dark-brown, thick, alkaline liquid, which contains about 10 per cent. of cresols, held in solution by soap, and a small amount of phenol. Mixed with water, it forms a turbid, whitish emulsion. According to Hünerman,[7] it is inferior to carbolic acid

[1] Deutsche medicinische Wochenschrift, 1887, No. 40.
[2] Zeitschrift für Hygiene, VI., 1889, p. 521.
[3] Archiv für Hygiene, XII., 1891, p. 359; XIV., 1892, p. 116.
[4] Zeitschrift für Hygiene und Infectionskrankheiten, XXIX., 1898, p, 377.
[5] Archiv für Hygiene, XXV., 1896, p. 328. [6] Loco citato.
[7] Centralblatt für Bakteriologie, V., 1889, p. 650.

against anthrax bacilli and pus cocci, but Van Ermengem [1] found it very effective in 5 per cent. solution against pus cocci and the germs of typhoid fever and cholera; and Laser [2] found that in the same strength it disinfects dejecta completely. The results obtained by various experimenters are, on the whole, very conflicting, but the output of many different manufacturers has been proved to vary very greatly in chemical composition and bactericidal power, and this is doubtless the cause.

Lysol is a brown oily liquid containing about 50 per cent. of cresols with neutral potash soap, miscible with water in all proportions, forming a soapy, frothing liquid, and with alcohol and glycerin. Gruber [3] found a 2 per cent. solution more effective against pus cocci than a 3 per cent. solution of phenol. Buttersack's [4] experiments led to the same conclusion, and demonstrated also its suitability for the treatment of sputum. Vincent [5] found it to be a valuable agent for the disinfection of fæces and vault contents. It has been used extensively in surgical practice with good results, but instances of poisoning through absorption from wounds, sometimes with fatal results, are fairly numerous.

Bacillol is a product of the distillation of tar, and contains variable amounts of cresols according to source, but should contain not less than 50 per cent. It is very cheap.

Lysoform is a cresol-formaldehyde preparation, soluble in water. It has great deodorant power, but is rather unsatisfactory as a germicide. It is also expensive.

Saprol.—This is a liquid containing 20 per cent. of mineral oil and 80 per cent. of crude carbolic acid. It is lighter than water, and when thrown into it diffuses over the surface in a thin layer, which gradually yields its active ingredients to the strata below, which, in the course of a day, become impregnated to the extent of about 0.34 per cent. In this strength, according to Scheurlen,[6] it destroys cholera bacteria in 1 hour. For the disinfection of privy vaults, Keiler [7] determined that it must be added to the extent of 1 per cent. of the entire contents. In mixtures containing 5 per cent., the same observer showed that the typhoid fever bacillus is destroyed within a few minutes. Pfuhl [8] found it to be much superior as a general disinfectant and deodorant to carbolic acid, but not suited to the treatment of vault contents. Laser,[9] however, found that 1 per cent. will disinfect fæces and urine; and Scheurlen [10] reported that for the disinfection of vault contents, but two other agents are comparable with it, namely, milk of lime and crude carbolic acid.

Solveol is a concentrated aqueous solution of cresols with sodium cresotinate, containing more than 25 per cent. of cresols. It is highly

[1] Centralblatt für Bakteriologie, VII., 1890, p. 75.
[2] Ibidem, XII., 1892, p. 232.
[3] Ibidem, XI., 1892, p. 117.
[4] Arbeiten aus dem kaiserlichen Gesundheitsamte, VIII., 1892, p. 369.
[5] Annales de l'Institut Pasteur, IX., 1895, p. 26.
[6] Archiv für Hygiene, XVIII., 1893, p. 35.
[7] Ibidem, XVIII., 1893, p. 57.
[8] Zeitschrift für Hygiene und Infectionskrankheiten, XV., 1893, p. 192.
[9] Centralblatt für Bakteriologie, XII., 1892, p. 234.
[10] Archiv für Hygiene, XIX., 1893, p. 347.

recommended for use in surgical practice, being unirritating and much less toxic than carbolic acid. According to Hammer,[1] it is more powerful in 2 per cent. solution than creolin, lysol, and carbolic acid in 2.5 per cent. strength. Hammerl [2] also found it superior to carbolic acid and the other cresol preparations.

Solutol is a solution of about 60 per cent. of cresols in sodium cresol. According to Hueppe,[3] it is far superior to creolin, lysol, solveol, and phenol, in which conclusion he agrees with Buttersack.[4] Hammer [5] also and others have found it to be well suited to the purposes of general disinfection.

Alcohol.—Ordinary alcohol is employed extensively as a preservative of organic material in great variety, and hence has come to be regarded as a powerful disinfectant as well as antiseptic. Koch's experiments showed that although the growth of anthrax bacilli was inhibited by 1 per cent., and wholly stopped by 8 per cent., the spores were unaffected by nearly 4 months' exposure to absolute alcohol, equal parts of the same and water, and mixtures of 1 part of alcohol and 2 parts of water. Sternberg and others have shown that against some forms of bacteria it is inefficient as a germicide in any degree of concentration, and that in different strengths it affects other forms to different extents. Epstein's [6] experiments led him to the conclusion that absolute alcohol is devoid of germicidal properties, and that, diluted with water to 50 per cent. strength, it exerts more action than at any other strength. Considerably stronger or weaker solutions show much diminished power.

Frank's [7] best results were obtained with 40 per cent. alcohol, which destroyed anthrax spores in 5 minutes. He found the vapor of 50 to 80 per cent. alcohol to be more or less productive of results, but that of 90 to 99 per cent. and of mixtures below 40 per cent. to be quite ineffective. W. von Brunn [8] came to practically the same conclusions, as did also Ahlfeld,[9] whose belief it is that the water in the mixture causes the envelope of the bacteria to swell and permits the entrance of the alcohol into the interior.

Minervini [10] found that, at ordinary temperatures, alcohol and its aqueous dilutions are powerless against spore-bearers, even with long exposure, and that, against the sporeless bacteria, the action is variable according to the amount of water present. The most powerful action was exerted by 50 to 70 per cent. alcohol. Heated under pressure in an autoclave, the power increases directly with the percentage of water. Many germicides which are effective in aqueous solution, appear to lose more or less of their power in alcohol. Minervini found 3 per

[1] Archiv für Hygiene, XII., 1891, p. 359. [2] Ibidem, XXI., 1894, p. 198.
[3] Berliner klinische Wochenschrift, 1893, No. 21.
[4] Arbeiten aus dem kaiserlichen Gesundheitsamte, VIII., 1892, p. 369.
[5] Loco citato.
[6] Zeitschrift für Hygiene und Infectionskrankheiten, XXIV., 1897, p. 1.
[7] Münchener medicinische Wochenschrift, 1901, No. 4, p. 134.
[9] Ibidem, 1901, No. 7, p. 265.
[8] Hygienische Rundschau, 1901, p. 111.
[10] Zeitschrift für Hygiene und Infectionskrankheiten, XXIX., 1898, p. 117.

cent. of carbolic acid in strong alcohol to act with undiminished energy, but observed that corrosive sublimate, nitrate of silver, and other agents were more powerful as the percentage of alcohol in the solution diminished. According to Epstein, not only carbolic acid, but also corrosive sublimate, lysol, and thymol are more powerful in 50 per cent. alcohol than in water, but other agents are weaker.

Lenti[1] has reported that while 0.4 per cent. of corrosive sublimate in absolute alcohol had no effect on anthrax spores in 48 hours, 0.1 per cent. in 98 per cent. alcohol destroyed them in half the time. Similar results were obtained with 10 per cent. of carbolic acid; in absolute alcohol, it was powerless, but in 30 per cent. alcohol, it killed them in 48 hours.

Essential Oils.—The volatile oils have long been known to possess a certain degree of antiseptic power, but bacteriological experimentation has failed to demonstrate that they are very active as germicides. Those highest in favor are the oils of peppermint, eucalyptus, and thyme, which contain, respectively, *menthol*, *eucalyptol*, and *thymol*. The latter was in somewhat extensive use in surgical practice prior to 1870. It is only slightly soluble in alcohol, ether, chloroform, and fixed and volatile oils. By many it has been regarded as superior to phenol. Spencer Wells much preferred it in his extensive experience in ovariotomy. According to Behring,[2] however, it is only about a fourth as powerful, and Sauter[3] ranks it even below salicylic acid. *Eucalyptol* is practically insoluble in water, but soluble in alcohol and other solvents. Concerning this agent, too, there is much diversity of opinion, some regarding it as vastly superior to phenol, others as much inferior. Lister praised it highly. Behring found it to be about equal to thymol. *Menthol* is sparingly soluble in water, but freely in alcohol and other solvents. It has been highly praised as a surgical antiseptic, and as freely criticised. Omeltschenko[4] ranks the oil of peppermint above that of eucalyptus, but below that of thyme. All three are placed by him below the oils of cinnamon and cloves.

Aside from the conflicting evidence as to the power of the various volatile oils, their cost alone would be sufficient to restrict their general use as disinfectants. They are employed considerably in various combinations in mouth washes and in a number of decidedly expensive proprietary disinfectants, one at least of which, tested by the author, has been found to be efficient in the sterilization of tuberculous sputum, one of the few uses for which its manufacturers make no claims.

Soaps.—It is well known that ordinary soaps, both hard and soft, are possessed of considerable bactericidal power, investigated first by Koch, who proved that potash soap in the proportion of 1 to 5,000 had a distinct inhibitory effect on the growth of anthrax bacilli, and in five times that strength prevented it altogether. This action was

[1] Annali dell'istituto d'igiene sperimentale della reale Universita di Roma, III., 1893, p. 515.
[2] Zeitschrift für Hygiene, IX., 1890, p. 395.
[3] Centralblatt für gesammte Therapie, VI., p. 376.
[4] Centralblatt für Bakteriologie, IX., 1891, p. 813.

admitted by Kuisl,[1] who, however, asserted that against other kinds of bacteria, *B. typhosus* for example, it was inert. In 1890, Behring,[2] after experimenting with 40 different kinds of soap, proved that their disinfectant power was considerable, and concluded that it was dependent upon their alkalinity. Koch, however, had demonstrated that, with equal degrees of alkalinity, soft soap was 8 times as powerful as potash alone; and Serafini[3] has pointed out that the free alkali present, even in concentrated soap solutions, is so small in amount that it can exert no disinfectant action whatever, and that neither the alkali nor the fatty acid, but the combination of the two, is the effective agent.

Nijland,[4] experimenting with a potash soap containing 47.2 per cent. of water and a hard soap containing 14.5 per cent., found that the former in 0.24 per cent. solution killed cholera bacteria in 10 minutes, and the latter in the same strength was not wholly effective in 15, but in 0.30 per cent. solution destroyed them within 1 minute. The cholera organism was used by Jolles[5] in testing five soaps, all of which proved to be inefficient. By 10 per cent. solutions, the bacteria were destroyed within 1 minute; by 4 per cent., in 10 minutes; by 2 per cent., and in three instances by 1 per cent., in 30 minutes.

In a later series of tests with typhoid fever bacilli, Jolles[6] tried an almost neutral soap, containing but 0.041 per cent. of free alkali, and with 1 per cent., sterilized a bouillon culture within 12 hours, with 3 per cent. within 2 hours, and with 6 per cent. in 15 minutes. He showed that the action was much influenced by temperature. The above results were brought about at temperatures between 4° and 8° C., but at 18° C., the time which elapsed before complete sterilization was accomplished was about double. This result is not in accordance with the general rule that disinfectants are more active with increased temperature. He obtained practically the same results with other varieties of bacteria, and reported that, because of its action on the most common pathogenic forms, soap is especially valuable and adaptable for precisely the kind of work in which it is the most natural agent; that is, in washing dirty and infected clothing.

Serafini,[7] however, is of the opinion that, in the ordinary washing of clothes, soaps exert but little disinfection, because of the many influences, hardness of the water, for example, which cause a diminution of their power. He recommends the avoidance of soft soaps, on account of the presence of all of the impurities of the fats and alkali from which they are made, and advises one to distrust the ordinary colored soaps, which are likely to contain rosin. If soap is the sole reliance, he recommends using it in strong solution at 30° to 40° C. (86° to 104° F.), and immersing therein for a number of hours the

[1] Inaugural thesis, Munich, 1885.
[2] Zeitschrift für Hygiene, IX., 1890, p. 395.
[3] Archiv für Hygiene, XXXIII., 1899, p. 369.
[4] Ibidem, XVIII., 1893, p. 335.
[5] Zeitschrift für Hygiene und Infectionskrankheiten, XV., 1893, p. 460.
[6] Ibidem, XIX., 1895, p. 130.
[7] Loco citato.

articles to be treated. Even with long soaking, Beyer[1] reports unvarying failure of soap against pus cocci and the bacilli of cholera and typhoid fever on clothing in hospital practice.

Reithoffer,[2] experimenting with common soft soap containing traces of free alkali and 2.55 per cent. of potassium carbonate, a white almond-oil soap perfumed with nitrobenzol and containing 0.062 per cent. of free alkali, and a patented potash soap containing 0.031 per cent. of free alkali, found that all three, even in 1 per cent. solution, were highly efficient against cholera germs within very few minutes, and, therefore, recommends soap as a practical disinfectant for clothing, furniture, etc., during epidemics of that disease. For washing body- and bed-linen, furniture, wood-work, floors, etc., he recommends a 4 to 5 per cent. soap solution as probably efficient under all conditions after from 5 to 10 minutes' contact, but suggests care in avoiding the common commercial soft soaps, which are frequently of poor quality. Experimenting with *B. typhosus* and *B. coli*, he proved that here again the soaps possessed a high degree of power, though much larger amounts were necessary than in the case of *B. choleræ*. He demonstrated that a 10 per cent. solution was necessary for the destruction of the typhoid germs within 1 minute, and that a 5 per cent. solution required from 3 to 10 minutes according to the kind of soap, the soft soap being slowest in action, as was true also against the cholera germs. Against the colon bacillus, the action was still slower: 5 per cent. of the almond soap required 15 minutes, and the same strength of potash soap failed to accomplish complete sterilization in 20 minutes. The superiority of the almond soap suggested the possibility that its increased power might be due to the nitrobenzol with which it was perfumed, and experiment showed this to be true. Against pus cocci, all three agents failed completely; *Staphylococcus pyogenes aureus* was unaffected by 20 per cent. solutions at the expiration of more than an hour. For the disinfection of the hands, 5 per cent. solutions were found to be almost immediately effective against cholera germs, but longer and more thorough washing is recommended in typhoid infection.

According to Mikulicz,[3] tincture of green soap, the German officinal *Spiritus saponatus*, containing 10.2 parts of potash soap, 0.8 of olive oil, 1 of glycerin, 43 of alcohol, and 45 of water, is admirable in undiluted form for sterilizing the hands in surgical work. They should be scrubbed for 5 minutes with the preparation in its full strength. In his experiments, *Staphylococcus pyogenes aureus* was killed in a half minute and *S. p. albus* in a minute.

From all the evidence, conflicting though it be in certain respects, it must be evident that in soap we have an agent which, with all its limitations, is entitled to very serious consideration, at least as an auxiliary in complete disinfection.

[1] Fortschritte der Medicin, 1897, No. 1.
[2] Archiv für Hygiene, XXVII., 1896, p. 350.
[3] Deutsche medicinische Wochenschrift, June 15, 1899.

Medicated Soaps.—In order to increase the disinfectant properties of ordinary soaps, various agents, including mercury compounds, carbolic acid, and the cresol preparations, are incorporated in them. Compared with ordinary soaps, these preparations appear to be of doubtful utility, although in the hands of some experimenters they have yielded good results. From an extensive investigation of these soaps, Symes[1] concluded that, for all practical purposes, most of them possess no added value, but that the mercury soaps are useful in disinfection of the hands. A 1 per cent. solution of the biniodide soap killed pus cocci in 1 minute, while the other soaps failed to do so in 3 hours. Nijland[2] found that the addition of disinfectants to soaps increases their action in some cases and diminishes it in others, the latter especially when the added substance combines with the ordinary constituents. According to his experiments, the most powerful of all is the corrosive sublimate soap, which, however, has less power than the corresponding amount of sublimate alone. In 0.003 per cent. solution it killed cholera bacilli in water within 10 minutes. Rideal[3] asserts that the double iodide of potassium and mercury has stronger germicidal powers than corrosive sublimate, and is easily incorporated in the soap stock. He recommends the admixture of 1 to 3 parts each of mercuric and potassic iodide in 100 of soap. "Potassio-mercuric iodide has the advantage of being compatible with strong alkalies. . . . Moreover, it does not precipitate albumin, and is not easily reduced." McClintock[4] tried to make an antiseptic soap in which the mercury salt should exist unchanged and active, and found the double iodide to be the most available agent in the proportion of 0.5 to 2.0 per cent. A solution containing 1 per cent. of the soap was found to be fatal to pus cocci and cholera, diphtheria, and typhoid fever bacilli in 1 minute. The soap attacked neither nickel, silver, aluminum, nor steel instruments, nor lead-pipes, and did not coagulate albumin.

Concerning carbolic acid and cresol soaps, the weight of evidence is clearly in support of the assertion that they are in no way superior to common soaps. Many contain no more than sufficient to make them powerful in odor, which is not sufficient to confer any marked bactericidal power. Nocht[5] calls attention to the solvent property of soap on carbolic acid, showing that at 60° C. a 3 per cent. solution of soap will dissolve 6 per cent., and double that strength will dissolve 12 per cent. of carbolic acid. He found that a cold solution of soap containing 1.5 per cent. of carbolic acid was fatal to pus cocci and non-sporing bacteria in half an hour, but recommends the employment of 3 per cent. solution of a 5 per cent. soap for the treatment of clothing, leather articles, and other objects. Reithoffer[6] found that carbolic acid is weakened by the presence of soap, and that a soft soap containing 40 per cent. of lysol was no more effective against pus cocci, *B. coli* and

[1] Bristol Medico-Chirurgical Journal, Sept., 1899.
[2] Loco citato.
[3] Disinfection and Disinfectants, London, 1898, p. 485.
[4] Medical News, April 17, 1897, p. 485.
[5] Zeitschrift für Hygiene, VII., 1889, p. 521.
[6] Loco citato.

B. typhosus, than ordinary soaps, and was much weaker than a solution of lysol alone in the same lysol strength. Tonzig[1] found that various creolin soaps were ineffective, like other soaps containing corrosive sublimate and other disinfectants, because new compounds are formed with the ordinary constituents of the soap, and the natural disinfectant properties of the same are thereby diminished.

In the disinfection of hands by means of medicated soaps, it should be borne in mind that the added disinfectant is commonly present in insufficient amounts, and that, as used, the soaps form a very weak solution, which, in the time ordinarily given, can have but little, if any, effect.

Formaldehyde.—Formaldehyde, otherwise known as methyl aldehyde and oxymethylen, the simplest known compound of carbon, hydrogen, and oxygen, was discovered by Professor A. W. Hoffmann in 1867, but its germicidal properties were not recognized until 1886, and were not put to practical use until 1891. It is a gaseous product of oxidation of wood alcohol, made most simply by passing a current of the alcohol vapor over platinum sponge previously heated; as the vapor comes in contact with the incandescent platinum, it is oxidized to aldehyde and water ($CH_3OH + O = CH_2O + H_2O$). The continuous current maintains the incandescence. On a large scale, it is produced by treating the alcohol in copper tubes containing incandescent coke.

Formaldehyde is soluble in water up to 40 per cent., and gives a neutral solution, but the commercial preparations are usually slightly acid in reaction from traces of formic acid. Its solution cannot be stronger than 40 per cent., and attempts to concentrate it or to condense the vapor cause it to polymerize to a white indistinctly crystalline solid, trioxymethylen or paraformaldehyde ($C_3H_6O_3$), which is almost insoluble in water, melts at 171° C., when ignited, burns with a blue flame, but when gently heated in an open dish, is converted again to the gaseous formaldehyde. When the solution is heated in a closed vessel under pressure, polymerization is prevented by the presence of borax or of neutral salts, as chloride of calcium.

Formaldehyde vapor is exceedingly pungent and very irritating to the eyes and nose. It has a strong affinity for many organic substances, and combines with nearly all foul-smelling products of decomposition, forming odorless compounds, and thus acting as a deodorant. It transforms gelatin in solution to a tough transparent substance insoluble in boiling water, causes blood serum to lose its coagulability by heat, combines with the protoplasm of bacteria, and converts egg albumin into a substance insoluble in water and indigestible. With ammonia, it forms an inert compound, hexamethylentetramin, which has the odor of neither substance ($4NH_3 + 6CH_2O = (CH_2)_6N_4 + 6H_2O$). It has no action on copper, brass, zinc, nickel, silver, iron, steel, or other metallic substances, causes no diminution in the tensile strength of fabrics, and has no bleaching or other effect on colors, excepting to intensify the effect of certain of the coal-tar dyes (fuchsin, saffranin,

[1] Gazetta degli ospedali e delle cliniche, 1900, No. 6.

and perhaps others). It may, however, fix blood, pus, and fæcal stains on clothing. It has no injurious action on clothing and other woven fabrics, furs, articles of rubber, leather, and paper, photographs, paintings, woodwork, and furniture.

The antiseptic properties of formaldehyde were noted first in 1886 by Loew and Fischer,[1] but its value as a practical disinfectant was made known first by Trillat[2] in a communication to the French Academy of Science in 1892, and since that time it has been the subject of very extensive investigation, which has demonstrated conclusively that formaldehyde is by far the most powerful and practical chemical disinfectant known. In general, it is used in the form of gas generated in different ways from methyl alcohol or from the aqueous 40 per cent. solution, commonly known by the commercial name Formalin, or from the solid polymer trioxymethylen, otherwise known as paraformaldehyde and by the trade name Paraform. In some processes of disinfection and deodorization, it is applied directly in the form of aqueous solution.

Methods of Use, and Apparatus.—At first, the gas was generated directly from methyl alcohol, by means of lamps specially constructed for the purpose. The first of these was devised by Trillat, who was followed by Gambier, Barthel, Dieudonné, Krell, Tollens, and others, who presented various modifications and improvements.

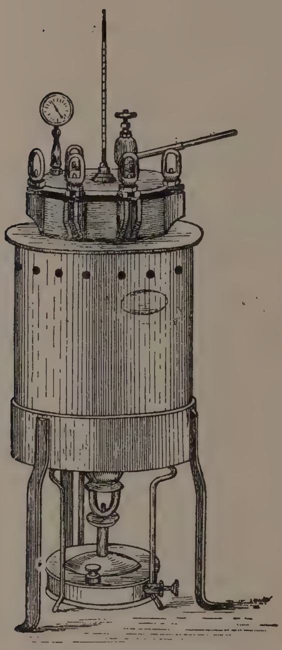
In 1896, Professor Robinson, of Bowdoin College, exhibited at the annual meeting of the American Public Health Association a lamp devised by him, which, it is generally agreed, is the best yet invented. It consists of a disk of moderately thick asbestos, closely perforated with small holes and platinized with a strong solution of platinic chloride, and a cylindrical dish upon which it is superimposed. In use, the dish is filled partly with methyl alcohol, and the disk, at first removed, is wetted with alcohol, which is then ignited. As soon as the alcohol is consumed, the disk is replaced, when it is at a sufficiently high temperature to convert the fumes from the methyl alcohol beneath to formaldehyde, and as long as the process continues, is maintained at the proper degree of heat. But this, in common with all other lamps of the kind, is open to several objections, among which may be mentioned the small yield of formaldehyde, which necessitates the employment of a large number of generators; the fact that a large, if not the greater, part of the alcohol is converted to carbon monoxide and dioxide, and the danger of fire.

Trillat, recognizing the defects of his own and other lamps, and being convinced of the futility of attempting to disengage the gas by evaporating the aqueous solution from open vessels, whereby polymerization is caused, attempted to devise an apparatus in which the aqueous solution could be employed without the occurrence of this undesirable phenomenon. The outcome of his study was the autoclave which bears his name.

[1] Journal für praktische Chemie, XXXIII., p. 221.
[2] Comptes rendus, CXIV., p. 1278.

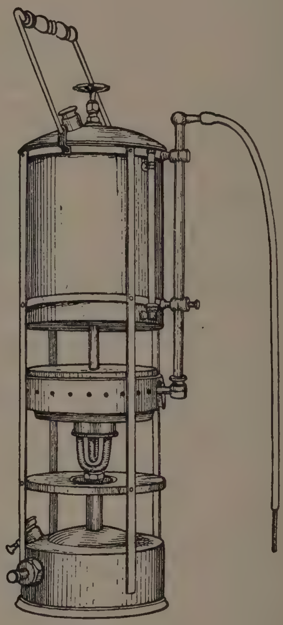
Trillat's autoclave, shown in Fig. 92, consists of a cylindrical silver-lined pot of heavy copper, of about a gallon capacity, with a cover resting on a rubber gasket and secured by means of turn-buckles. The cover carries a pressure gauge, a thermometer, and an outlet controlled by a valve and terminating in a narrow brass tube. The pot is supported on a tripod, and beneath it is a Swedish lamp, the flame of which is fed by vapors from kerosene oil forced out by compressed air. In the pot is placed not more than three-fourths nor less than one-fourth of its capacity of a mixture of the 40 per cent. solution of formaldehyde and chloride of calcium, the latter for the purpose of preventing polymerization under pressure. This mixture, which contains 150 grams of the chloride to the liter, is known as Formochlorol.

FIG. 92.



Trillat's autoclave.

FIG. 93.



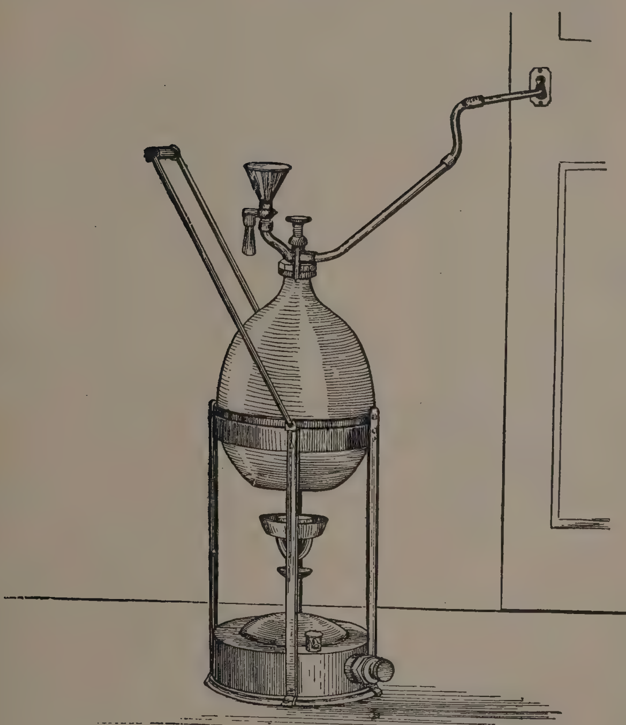
Sanitary Construction Company's regenerator.

The formaldehyde solution used should be practically free from methyl alcohol, which, while of no practical interest under ordinary circumstances, is an objectionable impurity when the solution is heated under pressure, since then it unites with a corresponding amount of formaldehyde to form inert methylal. The cover is firmly fixed by the turn-buckles, and then the lamp is put in operation. When the gauge shows a pressure of three atmospheres, the outlet tube is introduced into the keyhole of the door of the room to be disinfected, and the valve is opened gradually so as to release the vapor. The disengagement of the gas is

continued until a sufficient amount of the liquid, based upon the amount of air space treated, is consumed. According to Trillat, in the case of a room of ordinary size, say 18 feet square and 10 from floor to ceiling, the operation should require about an hour. The objections urged against this form of apparatus are its cost, the want of uniformity in the amount of gas delivered within a given time, and the danger of explosion from the possibility of the non-working of the valve, or from obstruction by one cause or another of the outlet tube.

A number of other apparatuses for the same purpose have been devised, and to several of them these objections do not apply. One of

FIG. 94.



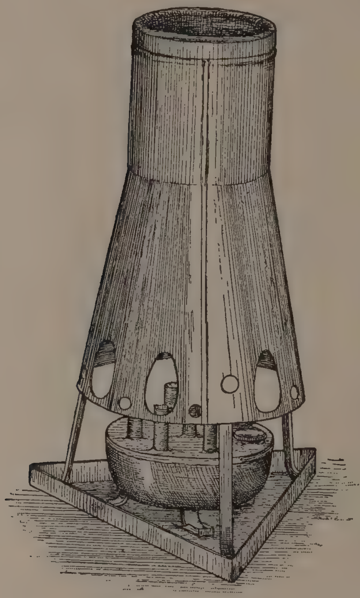
Lentz's regenerator.

these is the regenerator made by the Sanitary Construction Company, and used extensively by public authorities. (See Fig. 93.) It consists of a copper reservoir, holding about 3 quarts, from the bottom of which leads a quarter-inch copper tube, which forms a coil 2 inches below, and then turns upward and extends above the top of the apparatus, where it is fitted with a rubber tube carrying a fine copper nozzle, through which the gas is delivered. Beneath the coil is a Swedish lamp similar to that used with the Trillat autoclave. The formaldehyde

solution is admitted to the heated coil through a valve, and is transformed to vapor, which escapes through the nozzle. Neither pressure nor the presence of calcium chloride is necessary, and the rapidity of action and amount of solution used can be determined by observing the height of the liquid in the glass gauge on the side of the reservoir. The apparatus is very much cheaper than the Trillat and similar autoclaves.

Another regenerator which meets with favor is that of Lentz (see Fig. 94), in which the formaldehyde solution is heated in a retort by means of a Swedish lamp, the gas emerging through the metallic delivery tube connected by rubber tubing with the nozzle, which is inserted through a keyhole.

FIG. 95.



Schering paraform lamp.

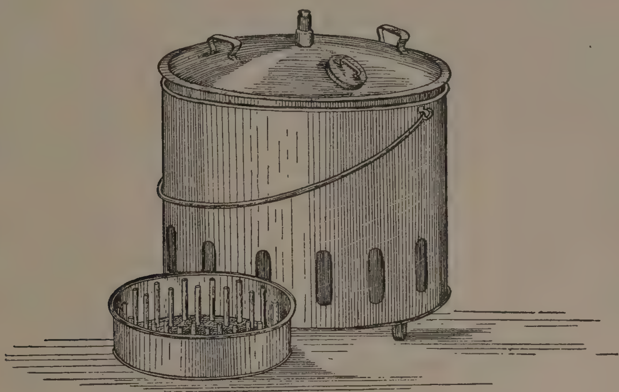
In order to avoid the use of the liquid preparation, and to employ in its place the solid polymer trioxymethylen, or paraform, the Schering lamp was devised, and in 1897 was brought into notice by Aronson,[1] after he had made a series of tests which yielded good results. This very simple and inexpensive apparatus, shown in Fig. 95, consists essentially of a metallic shell, not unlike an open piece of stove-pipe, supported on legs, and carrying in its upper part a basket made of sheet-iron and wire gauze, and an alcohol lamp carrying 6 or more wicks. For convenience, the paraform is supplied in pastilles weighing a gram each, and these are placed in the basket to the number of 2 for every 35 cubic feet of air space to be disinfected. The lamp is supplied with alcohol to the extent of 2 cc. for each pastille. The wicks should project not more than about a twelfth of an inch, which is sufficient to give a flame which will heat the basket and its contents sufficiently to cause volatilization of the agent, with absolutely no danger of its taking fire and thus yielding no formaldehyde gas. By the time the alcohol is consumed, the pastilles will have been volatilized completely or nearly so. If the space to be treated be of such size that the requisite number of pastilles cannot be placed in the basket, more than one apparatus should be used. This process has the advantage of simplicity and economy of time, for when the apparatus is placed in position with its lamp burning, it requires no further attention on the part of the operator, who then, with other lamps, is enabled to start the process elsewhere, and thus accomplish much more than

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXV., 1897, p. 186.

another who, operating an autoclave, or similar apparatus, is obliged to give it constant attention as long as the gas is being generated.

Still another apparatus is that used in what is known as the "Breslau method," in which the gas is disengaged in company with an abundance of steam, by boiling dilute formaldehyde solution. The

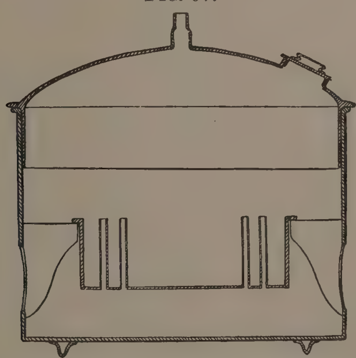
FIG. 96.



Breslau regenerator and lamp.

apparatus shown in Figs. 96 and 97, taken from the description of the method by von Brunn,[1] consists of a copper boiler about 14 inches in diameter and 3 in depth at the periphery, with an immovable cover slightly domed, in the center of which is an outlet tube, to which a stout rubber tube can be attached. The cover is provided also with

FIG. 97.



Vertical section of Breslau regenerator. (Lamp in position.)

two handles and an orifice closed by a screw cap. A flange around the upper border of the boiler keeps the latter in place when it is put on its support, which is a cylinder of enamelled sheet iron about 14 inches in height, provided in its lower half with slits for the free entrance of air, and on its inner side with three supports for an alcohol

[1] Zeitschrift für Hygiene und Infectionskrankheiten XXX., p. 201.

lamp. The lamp is an open dish, through the bottom of which, in two concentric rings, 20 tubes project upward as high as the sides of the vessel. With this apparatus, 3.5 liters (nearly 4 quarts) of fluid can be brought to boil in 10 minutes, and nearly the whole can be evaporated in an hour. The amount of alcohol placed in the lamp should be about one-fourth of the volume of the solution in the boiler, and this will be consumed before the boiler is empty. Like the Schering lamp, the apparatus may be left in the room or it may be used outside with a delivery tube passing through the keyhole. In order to achieve the best results, a dilution of 1 part of the 40 per cent. solution of formaldehyde with 4 of water is recommended. With this dilution, one avoids the polymerization observed when the undiluted solution is heated, which is due to the fact that the water is driven off faster than the formaldehyde.

A somewhat similar apparatus has been devised for the generation of steam in connection with the use of the Schering lamp. It consists essentially of a circular copper boiler, surrounding the Schering lamp and heated by a circular open alcohol lamp which is really a sort of gutter into which a measured amount of alcohol is poured.

In 1897, Rosenberg[1] described and attempted to introduce a simple form of lamp for the vaporization of formaldehyde from holzin, a dilute methyl alcohol containing 35 per cent. of formaldehyde and 5 of menthol, the latter being added in order to prevent the formation of methylal and to overcome any tendency to explode. The method has been tried by a number of experimenters, but the results have not led to its extensive employment.

A number of inventors have devised methods for spraying the 40 per cent. solution of formaldehyde itself, among them Lingner, Prausnitz, Flügge, and Czaplewski. The latter[2] disengages the gas by means of a jet of steam acting in a concentrated solution of formaldehyde, and presents figures showing the process to be the cheapest of all.

In 1898, Schlossman[3] advocated the use of a mixture of formalin and glycerin, which, by means of a steam jet from an apparatus of special construction, can be disseminated in the air in the form of a fine mist, which, being heavier than air, is supposed to settle and carry down all the bacteria mechanically. The mixture contains 10 per cent. of glycerin, and is called glycoformal; the glycerin is supposed to prevent polymerization as well as to act mechanically. According to Schneider,[4] the addition of glycerin is wholly unnecessary and disadvantageous, since this substance is deposited all about in fine droplets and makes cleaning more difficult. It is said also by van Ermengen[5] that, in addition to making objects slimy and wet, it often attacks the polish on furniture. Kaup,[6] Czaplewski,[7] and others agree that the addition of

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXIV., 1897, p. 488.
[2] Münchener medicinische Wochenschrift, 1898, No. 41.
[3] Berliner klinische Wochenschrift, June 20, 1898.
[4] Archiv für Hygiene, XXXVI., 1899, p. 127.
[5] Bulletin du Service de santé et de l'hygiène publique de Belgique, 1899, p. 28.
[6] Wiener medicinische Wochenschrift. 1899, Nos. 42–44.
[7] Münchener medicinische Wochenschrift, 1898, p. 1306.

glycerin is unnecessary. The process is also too expensive, and has the additional disadvantage of leaving an odor which is very lasting.

Another method of generating the gas which does away with special apparatus and also the need of a flame is that of Evans and Russell,[1] which depends upon the fact that when formalin and potassium permanganate are brought together, a violent reaction occurs, with the evolution of much heat and rapid liberation of the gas, and also vaporization of the water. Numerous experiments demonstrated that, for the attainment of the best results, 6.5 ounces of the permanganate in the form of powder or very small crystals should be employed with each pint of formalin. In any given case, the necessary amount of each having been determined, the permanganate is placed in a suitable vessel and the formalin is poured upon it. The evolution of the gas being very rapid, it is necessary for the operator to leave the room as quickly as possible. On account of the frothing which occurs in consequence of the violence of the reaction very tall vessels are required. Experience has shown that these are best made of tin and with flaring tops. It is recommended that they have a diameter of 10 inches at the bottom and a height of 17 inches, the sides having a perpendicular height of 8 inches and then flaring at an angle of about 50 degrees.

Quantitative determinations proved that the yield of gas averages 81 per cent. of the amount present in the solution, and that about four-fifths of this are set free within 5 minutes, the remainder being given off in rapidly diminishing amount during the next 12 hours. A very large number of bacteriological tests demonstrated that the method is entitled to be ranked as highly efficient.

Dieudonné[2] advocates the evaporation of diluted formalin with the aid of heated bricks, the liquid being poured over them, or of red-hot steel bolts, weighing about 7 pounds, held in a sheet-iron pocket in the vessel in which the liquid is contained. A perforated cover is employed to minimize the amount of loss of liquid by spurting.

Another simple method of generating the gas and steam at the same time is that of Schering,[3] in which pastilles of paraform and unslaked lime are employed. These are wet with warm water, and the heat which is produced in the process of slaking the lime is sufficiently intense to cause the volatilization of formaldehyde from the paraform and the formation of steam at the same time. One may use also unslaked lime and diluted formalin, dropping the former into the latter.

Germicidal Properties.—The first to note the antiseptic effect of formaldehyde were Loew and Fischer in 1886, but although Loew continued his observations for some months, and Buchner and Segall made a study of its antiseptic action in 1889, Trillat, in 1892, was the first to draw attention to the importance of the agent. Almost at the same time came a publication by Aronson.[4] Trillat reported that

[1] Thirteenth Report of the State Board of Health of Maine, 1904, p. 234.
[2] Die ärztliche Praxis, 1901, No. 2.
[3] Hygienische Rundschau, 1900, p. 708.
[4] Berliner klinische Wochenschrift, 1892, No. 30.

bouillon, infected with *B. anthracis*, was sterilized by 1 part of formaldehyde in 50,000, and that for the prevention of decomposition of meat juice, the agent acted as powerfully as corrosive sublimate in half the amount. Aronson reported that growth of *B. typhosis*, *B. anthracis*, and pus cocci in bouillon was prevented absolutely by 1 part in 20,000, and very much inhibited by 1 in 40,000. Then followed other experimenters, and within six years, formaldehyde had been the subject of more extensive investigation than has ever been devoted to any other germicide.

With the autoclave, Roux and Trillat[1] reported that a number of pathogenic bacteria, including anthrax spores, were killed; *B. subtilis* and *B. mesentericus* survived. Bosc,[2] at the same time, reported successful sterilization of a large number of varieties under different conditions in a large air space (more than 25,000 cubic feet), using 3 liters of formalin. Staphylococci in the pocket of a pair of trousers were destroyed, but others more protected escaped, although the colon bacillus between the two sides of a folded mattress, apparently still more protected, was killed. Of a large variety of species, including anthrax spores, *B. pyocyaneus*, and *B. diphtheriæ*, the only exposed organisms that escaped were *B. subtilis* and *B. mesentericus*. The dust and walls were quite sterile.

Pfuhl[3] found that all exposed organisms were destroyed by the Trillat method, but that dried *Staphylococcus pyogenes aureus*, anthrax spores, and *B. typhosus* under a nurse's apron, and others under a military overcoat, were not affected; diphtheria bacilli dried on threads and a fresh diphtheria agar culture under a woollen blanket were destroyed. Fresh typhoid agar cultures under a blanket were not killed; staphylococcus agar cultures were inhibited. Strüver,[4] with a Münke autoclave much like Trillat's, vaporized 800 cc. of formochloral in a room of about 1,250 cubic feet capacity, and after 12 hours, found that all organisms which had been exposed were dead, but that anthrax spores and *B. typhosus* in a tight closet and anthrax spores in the folds of upholstery of a chair were not affected.

With holzin, Rosenberg,[5] using about 4 cc. to the cubic foot of air space, sterilized all his test objects within 3 hours. These included anthrax bacilli and spores, streptococci, and the bacteria of diphtheria, cholera, and typhoid fever, all on silk threads wrapped in blotting-paper, placed in pockets and sleeves and under the collar of a coat, Strüver,[6] with the same agent in a like amount, was not so successful. He exposed, for 24 hours, anthrax spores on threads and the typhoid fever bacillus on pieces of linen; neither the spores nor the other organism protected by several layers of cotton cloth were destroyed. In another experiment, using much less holzin, the spores not protected by several layers of cloth were destroyed.

[1] Annales de l'Institut Pasteur, 1892, p. 283.
[2] Ibidem, 1896, p. 298.
[3] Zeitschrift für Hygiene und Infectionskrankheiten, XXIV., 1897, p. 289.
[4] Ibidem, XXVII., 1897, p. 357.
[5] Loco citato. [6] Ibidem.

The first experiments with paraform pastilles were those of Aronson,[1] who volatilized 2 pastilles to every 35 cubic feet, and at the end of 24 hours found that his test-objects, which included anthrax spores, staphylococci, streptococci, *B. pyocyaneus*, and the germs of tuberculosis, diphtheria, and typhoid fever, on gauze, threads, and other material were destroyed. He repeated the test with but half the amount of paraform, and again found everything sterile excepting the anthrax spores, some of which were still active. Gehrke,[2] using 2 pastilles to each 35 cubic feet, and with practically the same test-objects as Aronson had used, found, after 24 hours, that all that had been exposed were dead, excepting the anthrax spores. Fairbanks[3] with like amounts, reported similar results; all exposed organisms and some which had been lightly protected between pieces of cloth, and, in certain instances, others more completely protected by cloth and placed between bulky articles, were destroyed. In one series of tests, among the protected objects, only the typhoid and diphtheria organisms were killed, but, as usual, all the exposed germs were destroyed.

In a series of experiments by the author at the Pathological Laboratory of the Boston City Hospital in 1897,[4] as a preliminary test, only a fourth of the recommended number of pastiles were volatilized in a small room, in which were placed test objects, only one of which (a smear of *Diplococcus intracellularis meningitidis*) was sterile after 18 hours' exposure. With half the recommended number, the results were better, but not satisfactory. The test-objects introduced were paper smears of anthrax spores, *Staphylococcus pyogenes aureus*, *B. typhosus*, and a very resistant non-pathogenic spore-bearing bacillus. After 21 hours' exposure, these were found to be sterile without exception, but dust from several places in the room gave growths, although from others the results were negative. A surgical dressing, lying in a pail, yielded abundant growth before the experiment, but later was found to be quite sterile. Two Petri plates, exposed for 20 minutes after the room was aired, showed 7 and 4 colonies, respectively.

In the next experiment, the full recommended number of pastilles was employed. The test-objects were smears of the same organisms as before, but they were more numerous and were differently disposed. Some were enclosed in cotton bags heavily sized, some in similar bags which had had the sizing removed by boiling; some were placed in Erlenmeyer flasks, two of which were introduced well into the middle of a hair mattress. In addition, a number of moist dressings and wet bloody dressings enclosed in cotton bags were employed. After 20 hours' exposure, cultures were made, which showed the following results: The smears in boiled and unboiled bags and the slightly moist dressings, also enclosed in bags, were sterile without exception. The wet

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXV., 1897, p. 168.
[2] Deutsche medicinische Wochenschrift, April 14, 1898, p. 242.
[3] Centralblatt für Bakteriologie, etc., XXIII., Abth. I., Nos. 1, 3, and 16.
[4] American Journal of the Medical Sciences, Jan., 1898.

bloody dressings gave abundant growths. The flasks in the mattress agreed in results; the typhoid and staphylococcus smears in each were sterile, but those of anthrax spores and of the non-pathogenic spore-bearer were not affected. The same was found to be the case with the smears in a flask lightly plugged with cotton and standing in an open closet. All four smears in another open flask placed in a closed closet were unaffected. Dust cultures from various parts of the room were negative in almost every case. Before the lamps were lighted, 3 Petri plates were exposed for 25 minutes, and yielded, respectively, 86, 124, and 53 colonies, about half of which in each case were of *Staphylococcus pyogenes albus* with a few of *aureus*, and, in one, of *citreus*. Three more plates were exposed for the same length of time after the room was aired, and the result was practically negative. Two colonies of mould developed on one, and nothing whatever on the other two. A repetition of the experiment a week later with the same number of pastilles, but with only the original test-objects, gave the same negative results. Preliminary dust cultures showed abundant growths; after 20 hours' exposure, all but one dust culture, and that from a closed closet, gave negative results.

Power of Penetration.—Certain of the earlier, and an occasional one of the more recent, experimenters have claimed for formaldehyde a much greater penetrating power than can be explained by any law of physics or chemistry; but it is now very generally agreed that while this agent is beyond doubt the most powerful and practical disinfectant we possess for large air spaces and general work, it is, in the gaseous form, merely a surface disinfectant which sometimes does and oftener does not penetrate.

In addition to the works already quoted, the following may be cited. Abba and Rondelli[1] reported that, in the interior of a heap of clothing and on objects covered with clothes, no sterilization was effected. Doty[2] says that a careful analysis of reported results shows that it cannot be depended upon when deep penetration is required, but for superficial disinfection of furniture, clothing, and fabrics which may be freely spread out and exposed, it is of undoubted value. It can also be relied upon to penetrate letters and other thin packages placed in an air-tight chamber. To this last statement are opposed the results obtained by Dr. E. K. Sprague, U. S. M.-H. S.,[3] who, attempting to sterilize cultures in sealed envelopes with the Kinyoun-Francis disinfecting apparatus, failed every time. Experimenting with ordinary objects in a vacuum chamber heated to 90° C., with a vacuum of 15–20 inches, and with much more formalin than can be used under ordinary circumstances—360 cc. vaporized in 58 cubic feet—he finds that he cannot recommend it "even when combined with a high degree of heat, as a disinfectant upon which reliance can always be placed for

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXVII., 1898, p. 49.
[2] New York Medical Journal, Oct. 16, 1897, p. 517.
[3] Report on Formaldehyd Disinfection in a Vacuum Chamber, Treasury Department, Washington, Government Printing Office, 1899.

the treatment of articles requiring much penetration, especially when the exposure is limited to a half hour."

Wilson's[1] experience led him to report adversely on its penetrative power. Organisms protected by the folds of a blanket were not killed. Pfuhl[2] warns us against expecting more than it can perform, and says that it will always be only a surface disinfectant, not to be relied upon to influence matters only slightly covered or in dust which lies in measurable thickness in cracks of floors and walls. He demands a less severe test of a disinfectant than the ability to destroy anthrax spores, and asserts that when formaldehyde in the air will kill *Staphylococcus pyogenes aureus* dried on silk threads, other pathogenic organisms which enter into house disinfection, the streptococci and the bacteria of cholera, diphtheria, tuberculosis, and typhoid fever, will be destroyed.

It is important to bear in mind the lack of penetrating power of formaldehyde gas, since a disregard of this fact will cause much supposed disinfection to be a positive danger, because of over-confidence in the results actually achieved. Therefore, in practice, all obstacles to thorough dissemination must be removed as far as is possible.

Conditions Favoring Action.—Concerning the influence of moisture on the efficiency of formaldehyde gas, there is a decided difference of opinion. Abba and Rondelli[3] believe that dryness aids the process. Symanski[4] reports that it acts best in dry air with high temperatures. Robinson[5] regards dampness as a disadvantage. Trillat also believes that the presence of moisture makes the results uncertain. On the other hand, Strehl[6] is of the opinion that moisture enhances its action; Novy maintains the same view; and Hammerl and Kermauner,[7] commenting on the use of paraform pastilles, assert that the process is effective, if sufficient moisture is supplied, and recommend vaporizing four times the amount of water necessary to saturate the air at the existing temperature.

The results obtained by the author in the experiments above mentioned, and in other tests with cultures and decolorized fuchsin solution in tubes and flasks stopped with absorbent cotton, led him to the conclusion that penetration is influenced largely by moisture; "through dry pervious substances, as cotton cloth, absorbent cotton, hair, etc., it appears to penetrate more or less easily, but not always in sufficient amount to exert germicidal action. . . . In the presence of moisture the penetrating power is practically *nil*."[8] With this statement, Rideal[9] does not agree. He says: "Inasmuch as the vapor is so soluble in water, one would expect that materials previously moistened

[1] Brooklyn Medical Journal, Nov., 1897, p. 741.
[2] Zeitschrift für Hygiene und Infectionskrankheiten, XXIV., 1897, p. 289.
[3] Loco citato.
[4] Ibidem, XXVIII., 1898, p. 219.
[5] Ninth Report of the State Board of Health of Maine, 1896, p. 180.
[6] Centralblatt für Bakteriologie, etc., XXIX., 1896, p. 785.
[7] Münchener medicinische Wochenschrift, Nov. 22 and 29, 1898.
[8] Loco citato.
[9] Disinfection and Disinfectants, 2d Edition, London, 1898, p. 333.

would absorb more of the gas than dry fabrics, and therefore show greater efficiency, as I have found in my experiments." But when the gas is absorbed by moisture, it can no longer act as a gas, but as a solution which has influence *in situ*, and may give off fumes to the parts in its immediate vicinity. Rubner and Peerenboom[1] say that the dry gas has no influence on dry objects, but if the objects are too wet, the concentration of the formaldehyde solution, formed by absorption, is too weak to be effective.

The advocates of the Breslau method, von Brunn, Flügge, and others, regard the concomitant liberation of steam as a most essential part of the process, on the ground that, as the moisture condenses on the walls and contents of the room, the gas is absorbed and then acts directly on the object in the form of solution.

It is agreed very generally that a high temperature is most conducive to good results. Abba and Rondelli, Trillat, Symanski, and others whose works have been quoted, and Ivanoff,[2] are of this mind. Brough,[3] whose experience in public disinfection is large, reports that low temperatures are decidedly detrimental.

Toxicity.—Formaldehyde is commonly regarded as non-poisonous for higher organisms under ordinary conditions, and most experimenters who have confined animals in spaces undergoing disinfection have reported no permanently injurious effects. Aronson,[4] in 1892, noted the effects of the gas on guinea-pigs confined for an hour in an atmosphere strongly impregnated with it; they showed great discomfort and uneasiness, but on removal soon recovered completely. He reported some results of experiments by Zuntz, who determined the fatal subcutaneous dose for rabbits to be 0.240 gram per kilogram of body-weight. In Aronson's later experiments,[5] guinea-pigs and rabbits, left overnight in rooms containing an amount sufficient for practical disinfection, were found to be alive, and on being killed showed no evidence even of serious irritation of the bronchial mucosa.

Pottevin[6] found that a 2 per cent. solution in subcutaneous doses of 0.250 gram per kilogram was fatal to guinea-pigs in a few days, and that inhalation of the vapors was likewise fatal in 2 or 3 days. Trillat says that it is toxic only when inhaled many hours, but gives no definite number. De Schweinitz exposed a calf for 5 hours; it showed no particular distress and soon recovered completely in fresh air. Kobert exposed guinea-pigs for 36 hours without results. Fairbanks exposed mice and rabbits; Pfuhl, white mice; Doty, guinea-pigs, mice, fowls, and insects, and no deaths occurred. Doty's time of exposure was from 3 to 15 hours; he noted occasional evidence of inflammation of the respiratory tract, but nothing more.

Opposed to these negative findings are positive results observed by

[1] Hygienische Rundschau, 1899, p. 265.
[2] Centralblatt für Bakteriologie, XXII., 1897, p. 50.
[3] Transactions of the Massachusetts Medical Society, 1898.
[4] Berliner klinische Wochenschrift, 1892, No. 30.
[5] Zeitschrift für Hygiene und Infectionskrankheiten, XXV., 1897, p. 168.
[6] Annales de l'Institut Pasteur, Nov. 25, 1894.

Brough and the author. Brough[1] has repeatedly found that cats and dogs, accidentally overlooked in rooms undergoing disinfection, have been unable to survive even until the door was opened. He notes that flies are always killed, and bedbugs also, when not protected.

In an experiment conducted by the author[2] in a room of 7,660 cubic feet capacity, in which 650 cc. of formalin were vaporized, two rabbits were left over night in a wire cage. Soon after the gas began to be generated, both animals showed evidence of great discomfort, but at the end of 15 hours, when the room was opened, neither appeared to be much affected. But it should be noted that the amount of formalin used was not large for the air space—no more had been vaporized because of the inefficient working of the generator. On the following day, 2,150 cc. of formalin were used, and in the morning one rabbit was dead and the other alive, but breathing through the mouth with great difficulty; he improved noticeably within 2 hours, but died 36 hours later. Both animals were subjected to thorough examination in the Pathological Laboratory of the Boston City Hospital, from the records of which the following description, which evidences the very extensive poisonous action of the gas, is taken:

"No. 1. Section of the tongue shows nothing abnormal. Section of mucous membrane of the mouth shows desquamation of the surface epithelium with hemorrhage and infiltration, with lymphoid cells in the tissue beneath. Section of œsophagus is normal. There is no pneumonia. The liver shows marked injection, with granular and fatty degeneration of cells around the central veins of lobules. The lymphatic gland shows some dilatation of the lymph sinuses with hemorrhage. In the kidney there is slight degeneration of the epithelium.

"No. 2. In the liver there is considerable dilatation of hepatic veins, with some degeneration of liver cells in the centre of the lobules. The kidney is congested. The epithelium of the convoluted tubules is somewhat swollen and granular, and there is a small amount of coagulated albumin in the capsular space of the glomeruli. In many of the convoluted tubules there is more or less granular and circular reticulum, and, in places, desquamation of the cells. The spleen shows a slight amount of hemorrhage in the pulp. Pancreas shows no change. One of the lymphatic glands shows a marked degree of œdema, with formation of fibrin in the lymph sinuses. In the lung there is intense bronchitis with consolidation extending into the surrounding lung tissue. This is more marked in the very smallest bronchi. In one place, in the centre of a focus, there are numbers of short bacilli. The exudation of the alveoli is almost entirely purulent, with some large cells mixed with pus. In another place in the tissue there were numbers of large bacilli. There is only a slight amount of fibrin in the exudation. In another portion of the lung there were very much larger foci which were filled with organisms. All the blood vessels of the lung are greatly injected.

"It is difficult to explain the absence of bacteria in the cultures

[1] Loco citato.

[2] Ibidem.

made from the lung in the second case. The general character of the lesions in both cases shows the action of a soluble chemical poison on the tissues. The changes are much more marked in the second case than in the first, but in both they are of the same general character."

In another experiment in which the volume of formalin vaporized was not sufficient to destroy more than a small proportion of the test-objects, a number of roaches in a glass dish covered with wire gauze were killed; and in others conducted in a glass cabinet in which small volumes of formalin were vaporized, flies were very quickly killed.

Against mosquitoes, Rosenau[1] finds formaldehyde to be far inferior in all respects to sulphur dioxide.

Amount Necessary for Room Disinfection.—The amount of formaldehyde necessary to disinfect any given air space depends very much upon the thoroughness with which the escape of the gas is prevented during the time given for action. Under ordinary conditions and with the observance of all reasonable precautions, it is generally agreed that for each 1,000 cubic feet, a pint of formalin, or about 60 pastilles of paraform, ought to suffice. Strüver[2] would use 45 pastilles per 1,000 cubic feet against sporeless bacteria, but in practical disinfection one cannot always discriminate. Flügge[3] advises that, in small rooms containing the usual amount of furniture, the number of pastilles be increased from 2 to 2.5 per cubic meter, or to 72 per 1,000 cubic feet.

With the Breslau method, it is claimed that less than half a pint of formalin (190 cc.) will suffice for 1,000 cubic feet with 7 hours' exposure. Novy[4] also is of the opinion that in the presence of sufficient moisture, even less will be found adequate; namely, 150. Provided the gas is prevented from escaping, there can be no doubt that the smaller amounts are effective within much less time than that usually given in practical work. In a series of experiments in a practically air-tight glass cabinet, using as test-objects smears of anthrax spores, *Staphylococcus pyogenes aureus*, a highly resistent non-pathogenic spore-bearer, and the bacilli of diphtheria and typhoid fever, the author found everything sterile after two and a half hours' exposure to an atmosphere containing the equivalent of 110 cc. formalin in 1,000 cubic feet. Using it to the extent of about a pint to the 1,000 cubic feet, the same result was attained in less than a half hour.

Disadvantages.—The principal disadvantage observed in disinfection by formaldehyde, aside from its cost, which is considerable, is the odor, which is sometimes very persistent, especially when much moisture is present, and which, except under very unusual conditions, is plainly perceptible outside the room in which the gas is disengaged. Usually, however, this is a transient trouble, and is met by thorough aëration. If deemed advisable on the score of saving time, and when the gas has

[1] Bulletin No. 6, of the Hygienic Laboratory, Washington, September, 1901.
[2] Loco citato.
[3] Zeitschrift für Hygiene und Infectionskrankheiten, XXIX., 1898, p. 276.
[4] Medical News, 1898, p. 641.

been absorbed by the condensed moisture on the walls and furniture, it may be neutralized by means of ammonia water, which may be exposed in the room in shallow dishes or vaporized from a flask or other apparatus and conducted into the room by means of an outlet tube through the keyhole of the door. Flügge recommends the latter method, and advises the use of about 120 cc. of the 25 per cent. solution to each 100 cc. of formalin, and 320 cc. to each 100 pastilles of paraform used. Articles of clothing, stuffed furniture, and the like must otherwise require sometimes several days of airing.

Technic of Room Disinfection.—See under Practical Disinfection, page 561.

Other Applications of Formaldehyde.—Besides its use in the gaseous state for house disinfection, formaldehyde in the form of its aqueous solution is well adapted to the sterilization of urine, fæces, sputum, and other waste products, furniture, wood-work, toilet articles, and other objects, and it is also valuable as a deodorant. In the disinfection of urine, the addition of one-twentieth of its volume of formalin will be found to produce sterility within an hour. Tuberculous sputum and diphtheritic membranes, covered by a sufficient volume of a mixture of about two and a half tablespoonfuls of formalin in a quart of water, are sterilized within 2 hours. Liquid stools plus and equal volume of the same mixture are disinfected completely within the same period. Walter[1] states that, with 2.5 per cent. formalin (1 per cent. formaldehyde), fæces are deodorized in 1 minute, and that, treated with 10 per cent. solution, they are sterilized in 10 minutes. He states also that a 3 per cent. solution applied to the hands destroys all adherent organisms very quickly, especially if mixed with alcohol, but this can hardly be true.

A mixture of 1 part of formalin and 20 of water is very efficient as a wash for furniture, wood-work, and other objects, for spraying carpets and woollen clothing, etc., and for soaking bed-linen and other washable fabrics. A tablespoonful to a quart of water will remove all odor from the hands after autopsies, and will deodorize other parts of the body to which it may be applied.

Prevention of Dissemination of Infectious Material; Practical Disinfection.

Even with the best disinfectants available, and with the exercise of the greatest care in their application, practical disinfection is by no means always effective in preventing the transmission of infective material to new fertile ground. Hence it is advisable and necessary to keep the infected area as small as possible and to prevent the accumulation of infective material by destroying it continuously and as quickly as possible after it is thrown off by the body. With the exercise of due care, the waste products which act as vehicles for the infective agents of our common and occasional scourges may be so effectively dealt with from hour to hour and from day to day as to make the after-

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXI., 1896, p. 421.

treatment of the room and its contents somewhat of a mere form, carried out as a matter of routine practice, or in order to make assurance doubly sure.

According to the nature of the disease, these agents reside in discharges from the mouth, nose, and throat (diphtheria and pertussis), in sputum (pulmonary tuberculosis, influenza, and pneumonia), in discharges from the bowels (typhoid fever, cholera, dysentery, and tuberculosis), in the urine (typhoid fever), and in matters thrown off by the skin (acute exanthemata). Therefore, the course to be pursued during the continuance of a sickness or convalescence varies according to the nature of the disease.

The limitation of the infected area and of the amount of material which may require disinfection on the termination of the disease should be a matter for immediate action on the discovery of the existence of the disease. The patient, especially in the case of the acute exanthemata, should be placed in a room which, if possible, may be isolated from the rest of the house, and from which all unnecessary furniture, especially of the upholstered kind, hangings, carpets, and rugs have been removed. Disinfectants for the prompt treatment of infective matter should be kept near at hand, together with a sufficient number of appropriate vessels and utensils.

In order to prevent or restrict the carriage of living organisms from the room, ingress should be denied to all whose presence is unnecessary; the wearing of other than cotton and linen dresses, that is, smooth-surfaced and washable, by the attendants should be interdicted; no food remainder should be taken away to be consumed by others; no used bed-linen or body-linen removed until after immersion in disinfectant solutions, and no discharges finally disposed of until after appropriate treatment. If it be necessary to use the broom, the dust should be kept down by the use of wet sawdust or tea leaves, which, with the gathered dirt and dust, should be treated with disinfectant and burned.

Under no circumstances should the process known as "dusting," which is merely the scattering of dust through the air from surfaces where it was at rest and upon which and elsewhere it will again be deposited, be allowed, but such surfaces should be wiped with cloths moistened with or wrung out in disinfectant solution and afterward soaked and boiled. According to season, the windows should be provided with wire screens to keep out flies, which not only are an annoyance, but, through their habit of visiting all manner of excreta and other filth, act as carriers of infection.

Disinfection of Fæces. — The discharges from the bowels in typhoid fever, dysentery, cholera, and intestinal tuberculosis, should be received in vessels containing an amount of disinfectant solution equal to, or, better, larger than, the probable volume of the discharges. Whatever the agent used, it should be brought into immediate contact with the entire mass of the discharge by thorough mixing, and the whole should stand under cover for about an hour before final

disposition. Milk of lime, although efficient, leaves a bulky residue which cannot be conveniently disposed of through the usual channels. Chlorinated lime is also efficient, but is disagreeable in odor. Corrosive sublimate is unsuitable for reasons elsewhere stated. Phenol, in 5 per cent. solution, with or without the addition of mineral acids or common salt, and the various cresol disinfectants, may be employed, but their odor is not always tolerable to the patient. Dilute formalin presents no objections, and is very efficient and rapid in action.

Urine.—In typhoid fever and tuberculosis of the urinary tract, the urine should be sterilized by the addition of an equal volume of a 5 per cent. solution of chlorinated lime, carbolic acid, or one of the cresol compounds, but better by the addition of about a twentieth of its volume of formalin.

Sputum.—In pneumonia and pulmonary tuberculosis, the sputum should be received in spit-cups partly filled with disinfectant solution, and kept covered when not in actual use. It may be treated with 5 per cent. carbolic acid, or about 5 per cent. of any of the cresol compounds, or with 4 per cent. of formalin. Milk of lime and chlorinated lime are also efficient. Corrosive sublimate is very uncertain. By reason of its consistency and adhesive properties, sputum is one of the most difficult materials to sterilize. It is especially dangerous, as it may contain large numbers of entangled bacteria, which, on drying, may be disseminated by air currents.

Discharges from Mouth, etc.—In diphtheria and pertussis, all discharges from the mouth and throat should be received on pieces of rag, which should be burned. The diphtheria organism retains its vitality a long time in the dry state, and so may exist in the air of the room, if particles of false membrane which happen to be thrown out in coughing or sneezing are allowed to dry on walls, furniture, and elsewhere.

Eating Utensils, etc.—All eating utensils used by patients with pneumonia, diphtheria, pertussis, the exanthemata, and tuberculosis should be well scalded. All napkins should be treated in the same manner as infected bed-linen. All remains of meals should be destroyed.

Bed-linen and Clothing.—In any case of sickness in which isolation is advisable or in which the morbific agent is known to exist in the bowel discharges, all used body-linen, bed-linen, towels, napkins, wash-cloths, handkerchiefs, etc., even if not obviously soiled, should be immersed for an hour in disinfectant solutions, and then conveyed under cover to the laundry or other suitable place, and boiled for an hour. Should the organism survive the first treatment, which event with proper care is unlikely, it will perish in the second. Should there be no fæcal or other stains, the boiling may be carried out without the preliminary soaking; but in no case should the articles in a dry state be removed from the room except under cover or wrapped in a sheet wetted with an efficient disinfectant.

In scarlet fever, for example, the morbific agent, whatever it may

be, is exceedingly tenacious of life, and resides in the fine particles of epidermis which are continually cast off by the skin, and it is easily conceivable that an armful of linen from a case of this disease might shed, in its journey to the laundry, a number of dust particles capable of much mischief. Neither lime nor chlorinated lime may be used on clothing, on account of probable injury. Corrosive sublimate 1 : 1,000, phenols and cresols in 5 per cent. solution, and formalin in 4 or 5 per cent. solution, may be advised. Colored goods are sometimes affected by some of the cresol compounds, but to no greater extent than may be caused by ordinary laundry soap.

Hands.—In the nursing of cases of infectious disease, the soiling and infection of the hands are frequently unavoidable. After every use of the bed-pan, every wiping away of discharges, every handling of the patient's body, and, in short, after every act by which the hands may become infected, they should be washed immediately and thoroughly, although not necessarily with that thoroughness which is so essential in surgical practice. Ordinary soap-and-water treatment should be supplemented by the application of some more powerful disinfectant. Carbolic acid and the cresols may serve, but they leave a disagreeable smell, and have sometimes an unpleasant effect on the skin. Formaldehyde in 3 per cent. solution is efficient, but when applied frequently, causes a hardening of the epidermis which is far from agreeable. Corrosive sublimate 1 : 1000 is not so efficient, and its use is often followed by dermatitis. Schenk and Zaufal[1] recommend the use of sand soap followed by immersion in corrosive sublimate 1 : 1000, as hot as the hands can bear.

Air.—All attempts to disinfect the air of the sick-room in the presence of the patient are futile, for the presence of sufficient of any chemical disinfectant to have any effect on the bacteria present would cause the air to be irrespirable. It is a common practice to place about the room dishes containing carbolic acid, permanganate solution, chlorinated lime, iodine, and other agents, and to suspend sheets wrung out in all kinds of active and inert solutions, in the vain hope that thereby the air is made better for the patient and incapable of transferring infection to others. Whether the agent used is a true disinfectant in any strength whatever, and whether the sheet is continuously or only intermittently wet, do not appear to enter in any way into the question of efficiency. Ordinarily, anything sold in the shops at a high price and under a label alleging not infrequently the impossible, will be accepted without question. But it may safely be asserted that no disinfectant known can be of the slightest service when used in this way, and if this is true of the disinfectant, it must be of the sheet.

Much can be done to remove the well-known disagreeable sick-room smell, due to the excreta and to matters eliminated by the lungs and skin, but all hope of producing sterility of the air should be abandoned. If pathogenic organisms are present in the air, a much easier and more reasonable method of dealing with them is that of thorough

[1] Münchener medicinische Wochenschrift, April 10, 1900.

aëration, and this is one of the most important parts of treatment in general. The germicidal properties of sunlight should also not be overlooked when it is possible to make use of this important aid. If good ventilation is not sufficient to keep the air sweet, the old-fashioned pastilles, containing benzoin, may be employed as occasion demands, or one or two paraform pastilles may be volatilized slowly in a small lamp for the purpose. In very small amounts in the air, the gas is in no way disagreeable or irritating, and acts very powerfully as a deodorant, not by supplanting the smell, but by destroying it by chemical union.

Room Disinfection.—Not until the termination of the disease or the removal of the patient should the disinfection of the sick-room and its contents be attempted. This is not such an easy matter as is commonly believed, and much supposed disinfection is, by reason of a lack of thoroughness, no better than none at all, or, indeed, worse, because of undeserved confidence and unfounded sense of safety. Even with the utmost care, one can hardly expect absolute perfection of results, although in ideal disinfection every micro-organism present should be destroyed. Flügge,[1] who has devoted much time and study to the question of house disinfection, avers that with any process by which 90 per cent. of the pathogenic bacteria present are destroyed, one should be content, and that no process practicable will kill all of them.

The processes employed up to within very recent years are notoriously inadequate, and the far superior processes in use to-day may yet be made more perfect. House disinfection is often most insufficient, even when what has been done has been carried out with every care and under most favorable conditions, since it is the usual practice to disinfect only the particular room which the patient has occupied during his sickness, without regard to the fact that all the connecting rooms, hallways, and distant parts of the house may have become infected.

The open doorway opposes no unseen obstacle to the passage of minute dried particles of false membrane or epidermal scales floating in the air, nor are these attracted to and retained by the interposed sheet like particles of iron by a magnet. Even when the door is closed, there are air currents, now one way, now the other, under it and above the threshold. Infective material may be carried in one way and another by members of the family, visitors, attendants, and even by the patient himself, to various parts of the house, and the room in which he has lain ill may, by reason of proper attention, be the least infected one in the house, but yet in ordinary practice it is the only one treated. Probably oftener than not, much more than one room, and in not a small proportion of cases, the whole house, should receive attention.

The existing methods of room disinfection comprise mechanical treatment, direct application of disinfectant solutions as spray or washes, liberation of gaseous agents, and combinations of all three.

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXIX., 1898, p. 276.

The bread process, devised by Esmarch,[1] consists in rubbing the walls with pieces of bread, to which bacteria adhere with great tenacity. This is not applicable to rough walls, and when thoroughly and properly done, involves such an amount of labor and material as to be exceedingly expensive. The bread pieces, together with all crumbs which break off and fall to the floor, are carefully removed and destroyed by fire. For the rest of the room and its contents, other processes are necessary, including scrubbing with soft soap and water, wiping with disinfectants, and transportation of certain articles of clothing, furniture, bedding, etc., to the public disinfecting station to be treated by steam.

The method of treating walls, floors, furniture, and clothing by spraying with solutions of mercuric chloride and other agents commends itself in some quarters and not in others. According to Rideal, 35,000 houses in Paris were disinfected by means of sublimate spray, 1 : 1000, in 1893, and a still larger number in 1894 with satisfactory results and with no bad effects from the poison. It appears, however, according to later evidence,[2] that a number of the employés of the disinfecting squad have shown symptoms of mercurial poisoning, and Rideal mentions cases of salivation in India attributed to corrosive sublimate wash for floors. The spraying process, whether satisfactory or not, and whether dangerous to health or not, is not quick, and requires other treatment which consumes time and adds to the expense.

The ideal disinfectant would be a gas with no destructive or harmful action on anything but micro-organisms, capable of penetrating materials by which they are hidden, and acting with great quickness. Such an agent, it is safe to say, will never be discovered, for, even though the other requirements may be met, it is improbable that the physical law governing diffusion will ever be modified by any gas as yet undiscovered. Gaseous disinfection must ever be superficial or nearly so, and should be assisted by other methods to bring about the best results. Gaseous disinfectants which exert any injurious influence on the objects treated cannot be tolerated, and it happens that this class, which includes chlorine and sulphur dioxide, has been found wanting in efficiency.

Formaldehyde gas approaches more nearly the requirements of the ideal disinfectant than any thus far tried, and is rapidly supplanting all others. In its application, no matter how it is generated, whether from formalin or paraform, it is essential that every obstacle possible shall be interposed against its escape from the space under treatment, and that all objects within that space shall be so disposed as to present as much of their surface as possible to its action; and even then, absolute perfection of results cannot be attained. Flügge[3] relates that twice he prepared a small room, containing but little furniture, by placing pathogenic organisms on marked locations, and had the local disinfecting squad perform their office under careful supervision, and in both in-

[1] Zeitschrift für Hygiene, II., 1887, p. 491.
[2] Journal of State Medicine, IV., 1896, p. 146.
[3] Loco citato.

stances found that a fair percentage of the bacteria escaped destruction. He suggests, with good reason, that, in routine practice, the results must ordinarily be far less favorable.

For the attainment of the best results, the various articles of furniture should be moved away from the walls, all articles of clothing, blankets, and other textiles should be suspended freely on lines or clothes-horses, the pockets of clothing turned inside out, and all cracks and other outlets carefully stopped with wet cotton, putty, adhesive paper, or other suitable material.

Particular attention should be paid to the complete closure of all inlet and outlet registers; those in the walls should be pasted over with stout paper, and those in the floor should be so treated or covered with thick cloth wrung out in sublimate solution or diluted formalin. Loosely fitting window-sashes may be made tight by means of wooden wedges, and the cracks around them properly stuffed. If there is a stove in the room, its doors and openings for drafts should be securely sealed. Open fireplaces and Franklin stoves require complete closure of their flue-outlets. The doors of all closets and cupboards and the drawers of all bureaus and cabinets should be left open. All soiled places on the walls, floor, and furniture, possibly due to infective material, should be wetted with formalin or sublimate solution.

When the room has been properly prepared, the generation of the gas may be begun. If paraform lamps or the Breslau apparatuses are employed, the operator leaves the room and stops the crack under the door with wet cotton and closes the keyhole with a gummed label or with putty. If an autoclave or other similar apparatus is employed, the stopping of the keyhole of the door is necessarily deferred until the generation of the gas is completed. The room is then left unopened over night or, if the process is begun in the morning, through the day. On the expiration of the required time, ammonia in the necessary amount is vaporized through the keyhole, or the room is entered at once, the windows thrown open, and free aëration established. In the latter case, the operator's eyes should be protected by closely fitting goggles, and he should hold his breath, if possible, until his object is accomplished. If ammonia is employed to neutralize the gas, the room will be sooner inhabitable than otherwise, especially if steam has been generated simultaneonsly with the gas, as advocated by Flügge, for aëration may require many hours, and, in some cases, days, to rid the room of the odor. This is a matter of extreme importance with people of small means living in limited spaces, who cannot afford even the temporary inconvenience and expense of finding outside accommodations.

Mattresses which have been polluted by soakage of urine and excreta, thick clothing, and other articles which do not lend themselves to superficial gaseous disinfection, require treatment by steam in the special apparatuses described on a preceding page. Straw, corn-husk, and "excelsior" mattresses should be differently treated. Their contents should be removed and burned, and the ticking soaked in disin-

fectants and boiled. Stuffed furniture covered with woven fabrics should be taken out of doors and be well beaten and left exposed to the air and direct sunlight. If upholstered in leather, it should be well wiped in all the crevices with cloths wrung out in sublimate solution or diluted formalin.

Heavy clothing and other fabrics sometimes are sent to be treated by the benzene process, in the belief that, by this means, not only are grease spots removed, but that sterilization is effected. Rüpp,[1] however, has pointed out that, in the ordinary benzene process, pus cocci and the bacilli of typhoid fever, anthrax, diphtheria, and tuberculosis are not destroyed.

Disinfection of Books.—Books are extremely difficult to sterilize with certainty, on account of the protection that is given to bacteria by the juxtaposed pages. Unbound books may be subjected to treatment by steam, but this process is not suited to bound volumes, because of its effect on the glue. For bound books, the only available disinfectant is formaldehyde, but even this agent is not efficient, unless the leaves are so disposed that the gas can have access to every page. Books of value will require very thorough and repeated treatment; but those of small value, known to have been probably or possibly infected, are best destroyed by fire. If formaldehyde treatment is deemed advisable, they should be placed on edge, with the leaves opened as much and as freely as possible, and subjected repeatedly to the action of the gas in a tight closet or box.

Disinfection of Water-closets.—Water-closet bowls may be treated with dilute formalin or 5 per cent. solution of the cresol preparations. The wood-work around and near them may be washed with the same agents. Sublimate solution should not be used in plumbing fixtures, on account of its action on lead.

[1] Correspondenzblatt für Schweizerische Aerzte, 1897, No. 19.

CHAPTER IX.

MILITARY HYGIENE.

Since the most important factor in the efficiency of an army is its health, it follows that everything which may influence this in any way for the better or worse should be looked after with the utmost care. The men who compose an army are drawn from civil life, in which each individual has, to a greater or lesser extent, independent control of his time, choice of occupation, selection of food and dwelling-place, and general sanitary care. After enlistment, soldiers lose most of this independence; they are housed, clothed, fed, and exercised under regulations which it is beyond their power to amend; they are moved from one point to another, differing perhaps very widely in climatic and other conditions, under orders which they may not presume to question; their hours for sleep, meals, work, and recreation are fixed for them without consultation with them, and without regard to individual or communal preference.

Since the government necessarily deprives the soldier of his independence of action, it is bound by every principle of fairness to him to look after his health and comfort, to promote contentment, and to ward off ennui by all reasonable and proper means. Thus, the care of troops is a double obligation; the men have every right to expect it, and the efficiency of the army is dependent upon it. But no matter how careful the sanitary administration, it is a matter of common knowledge that in all wars, excepting the Franco-Prussian, and in that only with regard to the Germans, the mortality from disease has been far in excess of that from casualties, and in all armies, more discharges are due to sickness than to injuries.

The responsibility for the care of troops and health of camps is placed upon the medical officers, who have no power to command and are hampered by being subordinate to laymen having often no adequate appreciation of matters purely medical. They have only advisory functions, and must be most careful in recommending changes to the very conservative military mind, which finds in long continuance of a condition the strongest argument for its longer retention, and is prone to look upon recommendations for sweeping changes as evidence of whimsical disposition and deficient training in sanitary science. Nevertheless, the medical officer has a very heavy responsibility placed upon him, and must advise his lay superiors and explain the importance of the principles underlying sanitary practice. He must make proper recommendations for the protection of health of the troops in war and in peace, in camps and in garrison.

Since the efficiency of a military body is so largely dependent upon the health of the units of which it is composed, the result of a campaign may be largely influenced by the adoption or rejection by the commanding officer of the recommendations of his medical adviser. Unfortunately, if, by reason of physical unfitness of the troops, a movement fails or an epidemic of disease occurs, the public at once places the blame upon the medical department, and especially upon the head thereof, the Surgeon-General, and demands a reorganization, a sifting out of incompetent material, and especially, a change in the head, quite regardless of the possible fact that the choice of an unsanitary camping place may have been made against the judgment and advice of the medical branch, that the commissary department may have been largely to blame, or that other influences quite beyond the control of the medical corps may have been at fault.

The medical officer, both at home and in most countries abroad, has much with which to contend. The corps is, as a rule, not sufficiently large for the body for which it is to care, but is expected to perform an amount of work and assume a responsibility which would fairly tax the capacity of one of double size. In an emergency requiring large additional levies and consequent employment of civilian physicians untrained in military life, the responsibility becomes proportionately greater.

The recent experiences of this country and of England, when the outbreak of war necessitated the assembling and transportation of large armies, serve very well as illustrations. With us, on the breaking out of war with Spain, a standing army of 25,000 was suddenly increased by enlargement of the regular service and enrollment of volunteers to ten times that size, but the small body of trained military surgeons, too small before, could hardly have been expected to be equal to the demands of the new army, even with the assistance of the physicians from civil life, who, although doubtless highly efficient in civil practice, were for the most part inexperienced in camp hygiene. The difficulties of sanitary administration were very largely increased by the recklessness and ignorance of the volunteers in personal hygiene and general sanitation. The results were what might be expected, and are too well known to need further mention. The blame for all the disastrous experience was placed at once upon the medical department, which had but little to say in the choice of camps, and nothing whatever to do with the inadequate means of transportation and other factors in the production of a large mortality from disease. The experience of the English in the war in South Africa was essentially the same, and was due to the same causes.

In the large standing armies on the Continent, a different order of things obtains. The officers of the line are more inclined to defer to the opinions and advice of the medical staff in matters requiring expert sanitary knowledge, and the authorities demonstrate a much higher appreciation of the value of an adequate medical service. As an

illustration of the difference in the ordering of such matters in Germany and England, the following is cited:

The British first infantry division and first cavalry brigade, with two batteries of field artillery, a company of engineers, telegraph corps, railway company, ammunition corps, and hospital corps, ordered to South Africa in the autumn of 1899, and the German expeditionary corps, consisting of two brigades of infantry, three squadrons of cavalry, four batteries of light artillery, a batallion of pioneers, with a telegraph corps, railway company, sanitary company, ammunition corps, and hospital corps, organized in the summer of 1900 for service in China, were about equal in number of men. For the care of these troops, the English authorities detailed 49 regular medical officers and 13 civilian surgeons, a total of 62; the Germans detailed 91 regular army surgeons, or nearly 50 per cent. more. The English hospital ship had 3 surgeons; the German had 10. The English sent 4 field hospitals with 16 surgeons; the Germans sent an equal number with 24. The English general hospital had 18 surgeons, of whom 11 were civilians; the German had 19, all of whom were regulars.

The superior medical equipment of the Germans is not dictated by extravagance, but by a greater appreciation of the necessity of furnishing adequate medical service.

In a standing army such as is maintained in this country, it would be far better to err on the side of extravagance than of undue economy in the size of the medical corps. There should be systematic instruction in general hygiene, which should not be limited to the medical officers alone, for the line officers also should be required to acquaint themselves with the principles of the science, and especially with the sanitation of camps. Then, when the medical officers point out methods of conserving the health of troops, those in actual command would be in a better position to apply their authority with a larger appreciation of the advice given.

Military hygiene has to deal with the selection and examination of men offering themselves as recruits, their habitations, clothing, exercise, food, diseases, and medical care; with camp sanitation, including water supply and sewerage, disposal of waste, and general police; and, in general, with all matters having any bearing on the health and, impliedly, the efficiency of troops.

THE RECRUIT.

Not every adult man accustomed to hard work can be transformed into a good soldier, for there are many points of disqualification for military service, and an unsound man can never be depended upon when his services are needed. The ideal recruit is one who, in the first place, is well built and of superior muscular force, capable of resisting influences tending to depress the nervous and physical powers. According to the great Napoleon, "The first quality of a soldier is the power to endure fatigue and privation; courage is only second." This

primary qualification is very commonly thought to be an attribute more of the country-bred than of the city-bred lad.

Dr. Woodhull,[1] Lt.-Colonel, Med. Dep't U. S. A., however, says on this point: "In raising new troops, when it is possible to select, for sharp and immediate active service take town-bred men. If a year or two can be added in which to train them, take country-bred men. Open-air military life is physical promotion to city men accustomed to irregular hours, unwholesome meals, and poorly ventilated rooms. To country lads the irregular and sometimes scanty meals, broken rest, necessity for prompt and exact action, and above all the certainty of acquiring such diseases as measles, whooping-cough, and mumps, which town boys always have in childhood, are very exhausting. After a year's training, country youths are more valuable."

Under the regulation of the United States Army,[2] any male citizen or person who has legally declared his intention to become a citizen, if above the age of 21 and under the age of 35 years, able-bodied, free from disease, of good character and temperate habits, may be enlisted; but in regard to age or citizenship, the rule does not apply to soldiers who have already served honestly and faithfully a previous enlistment. Boys between the ages of 16 and 18 may be enlisted as musicians or to learn music, with the written consent of father or guardian and approval of the Adjutant-General.

Enlisted men of good character and faithful service, who, at the expiration of their terms, are undergoing treatment for injuries incurred or disease contracted in the line of duty, may reënlist, and if the disability prove to be permanent, they will be subsequently discharged. An enlisted man, not under treatment, but with infirmities contracted in the line of duty not such as to prevent his performing the duties of a soldier, may be reënlisted by authority of the War Department, on application made through the surgeon and proper military channel, since it is recognized that what he may lack in some minor particulars in soundness may be counterbalanced by experience and habits of discipline.

Those whose enlistment is prohibited include former soldiers having bad record, deserters, drunkards, insane persons, minors below 16 years of age (musicians), persons who have been convicted of felony or who have been imprisoned under sentence of a court; and for first enlistments in time of peace, non-citizens, except those who have legally declared their intentions to become citizens, those who cannot speak, read, and write English, and those over 35 years of age.

Age.—Recruiting officers are directed by the regulations to be very particular to ascertain the true age of the recruit, boys below 18 not being accepted in time of peace, excepting as musicians or to learn music, and then only with the consent of guardians and approval of the Adjutant-General. The minimum age for all arms of the service is 18 years; the maximum for the cavalry is 30, and for other arms

[1] Notes on Military Hygiene for Officers of the Line, New York, 1898, p. 18.
[2] Regulations for the Army of the United States, Washington, 1899, p. 113.

35; but for reënlistments there is no limit of age. Men of all ages between 18 and 45 are accepted in the volunteer service. In the British service, the limits of age are 18 and 25 years, except for the medical staff corps and engineers, for which the maximum is, respectively, 28 and 30.

It is almost the universal opinion that recruits ought not to be accepted below 20, or, better, 22. At 18 years, the recruit is immature; the bones are not fully formed, nor have they reached their final hardness; the epiphyses have not become incorporated with the shafts of the long bones; the joints are not fully developed; the muscles are soft and not wholly developed; the chest has by no means attained its full capacity; and the organs of the body, in general, are immature. So it happens that, at this age, it is useless to expect them to be in good condition after long-continued exertion or to undergo privations which are as nothing to the man of mature years and strength. At this period of life, he is still in the growing stage and needs all the energy of his body to bring the organism to completion, and the influences which mature soldiers contend against with varying degrees of success, namely, vicissitudes of weather, long marches, hard work in trenches, possible overcrowding in barracks and camps, poor ventilation, and poor and insufficient food, send him very quickly to the hospital.

It is beyond reason to expect the same work and endurance of a youth of 18 to 20 as of a fully mature man. During the Civil War, most of the boys who enlisted under 18, and many of those above that age and under 20, had to be discharged within the first few months.

It has been demonstrated repeatedly that the least efficient armies are those containing the greatest proportion of men below the age of 22. The first Napoleon objected to boys, saying on one occasion, "I demand a levy of 300,000 men. But I must have grown men; boys serve only to fill the hospitals and encumber the roadsides." A remarkable example of the importance of maturity in soldiers is related by Tardieu.[1] In the campaign of 1805, in which the army marched 400 leagues to reach Austerlitz, hardly any sick or stragglers were left on the way. In this army the youngest were 22 years of age and had had two years' training. In the campaign of 1809, on the other hand, the army, which had but a short distance to march on its way to Vienna, filled all the hospitals on the way with its sick. More than half the soldiers of this army were under 20 years of age and inexperienced. In the celebrated march of Lord Roberts from Kabul to Kandahar, the young soldiers gave out from day to day and fell behind, while the old campaigners appeared to gain in vigor with each day's march.

Not only are young recruits less able to undergo the usual work and the hardships than seasoned men, but they are much more susceptible to disease. Aitken[2] relates that, during the Crimean War, when the

[1] Dictionnaire d'Hygiène, III., p. 2.
[2] On the Growth of the Recruit and Young Soldier, 2d Edition, London, 1887, p. 58.

Commander-in-Chief, Lord Raglan, was informed that 2,000 recruits were ready to be sent to him, he replied: "Those last sent were so young and unformed that they fell victims to disease and were swept away like flies." He preferred to wait rather than have such young lads sent to him as soldiers. Other commanders in the Crimea testified that young recruits were of very inferior value.

The greater susceptibility of young soldiers to typhoid fever was demonstrated by Dr. Farr, the British Registrar-General, and by Dr. Balfour, who showed that, in 1883, the army in India contained 41 per cent. of soldiers under 25 years of age, and that among this contingent the death-rate from this disease was 4.34 per thousand, while that of the men of 25 to 29 years was but 1.50 per thousand. In newly-arrived regiments, nearly half of the total death-rate was from this disease. Aitken gives a number of instances of the influence of youth and short residence on the prevalence of this fever. At one station, for example, out of 44 cases, 35 occurred in one regiment composed principally of young soldiers, and 33 among men of less than one year's residence in India.

In 1883, in India, 36.55 per cent. of those invalided home were under 25 years of age, and in 1884, 38.70, the principal diseases necessitating invaliding being anæmia, debility, phthisis, hepatitis, and diseases of the heart and arteries. Throughout the Peninsular War, from 1805 to 1814, it was observed that the "corps which arrived for service were always ineffective and sickly in proportion as they were made up of men who had recently joined the ranks," and it was calculated that 300 men having five years' experience were worth more than 1,000 newly-arrived, including the usual proportion of young recruits.

Surgeon-General Sternberg, of the U. S. Army, in his annual report for 1885, shows that the greater proportion of sickness occurred among soldiers under 31 years of age, and that up to the age of 25, the rate was so much above the average for the whole army, that he questions whether their services had been a fair return for the cost of their maintenance. In 1899, the British Medical Association passed a resolution requesting the Council to communicate to the War Office the opinion of the Section of Medicine, that no soldier ought to serve in the tropics earlier than 22 years of age.

In favor of the young recruit, Woodhull says that young men are more easily trained and moulded than older men, especially for the cavalry, and when well led, fight as well, as far as mere courage goes. But as we cannot keep young soldiers several years in training, and as large bodies of troops can only be raised for sudden war, men not absolutely mature must be rejected. Lord Wolseley prefers young men, and says:[1] "Give me young men: they do what they are bid, and they go where they are told; they become more amenable to discipline, and though when you catch them first they may have some difficulty in carrying their knapsacks, once they get beyond that they are in a fit condition to take the field."

[1] Quoted by Aitken. Loco citato.

If young men are enlisted, the work should be suited to their strength, and it should be kept in mind that they are still in the growing and developing stage, and should have no greater amount of physical exercise than is suited to their condition. In other words, their work should be proportioned to their growth, and in two years they will, perhaps, have developed into valuable soldiers. Taken between the ages of 18 and 20, and drilled and trained with due regard to his immaturity and limit of endurance, the recruit often shows great progress in general development within the first half-year, particularly if, before enlistment, he was poorly fed, clothed, and housed, and engaged in an indoor occupation. His work should be moderate in the beginning and only gradually increased, since changes for the better in the human body cannot be brought about suddenly like those for the worse, induced by attempting to do too much at the outset. Since his lungs, heart, and blood-vessels are not yet fully developed, he can neither go through the manual nor cover ground like the seasoned soldier. The heart is called upon by the new and unaccustomed exercise to contract at a greater rate than had been its habit, and he soon becomes "winded." When this stage is reached, and he begins to feel or show distress, he should be allowed and encouraged to rest until the throbbing of the heart and the swelling of the blood-vessels subside and permit his lungs to resume easy breathing; otherwise, he is more than likely to break down sooner or later. With properly regulated exercise and good food, he ought soon to show gain and not loss in weight. Should progressive loss be observed, it is a question whether he is likely to become an efficient soldier, and he should forthwith be referred for medical examination. Under the regulations of the British army, all recruits are kept under medical observation during the first three months of service, during which time, in addition to the ordinary drill, they have an hour of gymnastic exercise daily, under the supervision of a medical man; and if, during this period, a man shows unfavorable indications, he is examined by a medical board. Should this body conclude that he will not ultimately develop into an efficient soldier, he is at once discharged on that ground.

Height.—In this country, the minimum height for all branches of the service is 5 feet 4 inches, "although recruiting officers are allowed to exercise their discretion as to the enlistment of desirable recruits (such as band musicians, school teachers, tailors, etc.), who may fall not more than one-fourth of an inch below the minimum standard of height." The maximum for the cavalry alone is 5 feet 10 inches, and for all other branches, according to weight. The minimum height is subject to change, if necessary; but it has been demonstrated that 5 feet 2 inches is about the lowest limit for efficiency, men below that height having proved, as a class, to have comparatively little staying power, and to break down for want of strength. In the British army, the minimum for the infantry is the same as with us; the limits for the cavalry are 5 feet 6 inches to 5 feet 11 inches; for the household cavalry, 5 feet 11 inches to 6 feet 1 inch. In the French army, the

minimum for Cuirassiers is 5 feet 7 inches; for the infantry 5 feet 1 inch.

Military organizations composed exclusively of very tall men of imposing appearance, are intended for display, and not for the usual work of the soldier, and, indeed, have often proved to be lacking in the essentials of good soldiers, unless they are unusually well-proportioned. The superiority of additional height is commonly found to lie in the leg and neck, and when 6 feet 3 inches is exceeded, the individual, as a rule, is not proportionately developed in the chest and muscular system. Such men are said to be more prone to diseases in general, and more especially to pulmonary complaints, than men of medium height, and they become fatigued more early on the march and under all circumstances where endurance is of the first necessity. Their muscles are longer, possess less fasciculi, and work longer levers than those of the short men. They also offer a better target for the enemy. On the other hand, very short men are quite as objectionable as their over-tall comrades. During the Civil War, the smallest men enlisted broke down, as a rule, after but a few weeks' service in the field. There are, of course, exceptionally short men who are unusually muscular, but, as a class, they are wanting in strength.

Weight.—In this country, there is no minimum weight for the cavalry, "in which enlistments may be made without regard to a minimum, provided the chest measurement and chest mobility are satisfactory." The maximum for this branch is 165. In all other branches, the minimum and maximum are respectively 128 and 190, but a recruit, exceptionally good in all other respects, may be accepted in any branch at 120.

Examination of the Recruit.—The first step in the examination of a recruit is thorough washing with soap and water. "It is not believed to be good policy to enlist men who, though able-bodied and intelligent, appear at recruiting stations in ragged or filthy dress, as the chances are such men are tramps and vagabonds and will not make good soldiers. Men who, though attired in clean and respectable clothing, are found to be filthy in their persons, should be promptly rejected for like reason."[1] He is then presented to the examining officer without clothing, in a well-lighted room large enough for exercise in walking, running, and jumping. Here, he is subjected to a searching physical examination, and each deviation from the normal standard is noted. In addition, his family and personal history are obtained of the applicant, whose replies to the prescribed questions are recorded with such other information as bears on his fitness for the duties of a soldier. This inquiry is made before the physical examination is begun.

The examination is very thorough, and includes the mental condition, the senses, the principal organs of the body, the general formation, the chest capacity, the condition of the teeth, skin, joints, and feet, and the presence or absence of hernia, varicocele, and other disqualifications.

The leading characteristics of a good constitution, as enumerated by

[1] Manual for the Medical Department, Washington, 1898, p. 65.

Dr. C. S. Tripler, U. S. A., are as follows: "A tolerably just proportion between the different parts of the trunk and members, a well-shaped head, thick hair, a countenance expressive of health, with a lively eye, skin not too white, lips red, teeth white and in good condition, voice strong, skin firm, chest well formed, belly lank, parts of generation well developed, limbs muscular, feet arched and of moderate length, hands large. The gait should be sprightly and springy, speech prompt and clear, and manner cheerful. All lank, slight, puny men, with contracted figures, whose development is, as it were, arrested, should be set aside. The reverse of the characteristics of a good constitution will indicate infirm health or a weakly habit of body: loose, flabby, white skin; long, cylindrical neck; long, flat feet; very fair complexion; fine hair; wan, sallow countenance."

On being accepted, the recruit must be vaccinated immediately, unless there is unmistakable evidence of successful vaccination within a reasonable period.

Chest Capacity.—The determination of chest capacity is of great value and importance, since it furnishes an index of the vigor of the candidate. The factors employed are the chest measurements and extent of mobility. The chest girth is measured by means of a tape-measure passed round on a line including the lower portions of the scapulæ and on a level with or just below the nipples. It is taken at forced inspiration and forced expiration, and the difference in the two measurements represents the chest mobility, which is one of the best indications of capacity for endurance, and is of much greater value than the actual maximum and minimum circumferences, since a very large chest may have less mobility than one considerably smaller. For men under 5 feet 7 inches, the mobility should be not less than 2 inches; between that height and 6 feet, not less than 2.5 inches; 6 feet and above, not less than 3 inches.

Chest girth, weight, and height are very closely correlated in the growth and development of a healthy man, and these proportions should be carefully observed. The following table of physical proportions is taken from the Manual for the Medical Department:

Height.		Weight.	Chest measurement.	
Feet.	Inches.	Pounds.	At expiration. Inches.	Mobility. Inches.
$5\frac{4}{12}$	64	128	32	2
$5\frac{5}{12}$	65	130	32	2
$5\frac{6}{12}$	66	132	$32\frac{1}{2}$	2
$5\frac{7}{12}$	67	134	33	2
$5\frac{8}{12}$	68	141	$33\frac{1}{4}$	$2\frac{1}{2}$
$5\frac{9}{12}$	69	148	$33\frac{1}{2}$	$2\frac{1}{2}$
$5\frac{10}{12}$	70	155	34	$2\frac{1}{2}$
$5\frac{11}{12}$	71	162	$34\frac{1}{2}$	$2\frac{1}{2}$
6	72	169	$34\frac{3}{4}$	3
$6\frac{1}{12}$	73	176	$35\frac{1}{4}$	3

"It is not necessary that the applicant should conform exactly to the figures indicated above, a variation of a few pounds from either side of

the standard in the minimum and maximum weights and of a fraction of an inch in chest measurement being permissible if the applicant is otherwise in good health and desirable as a recruit. The table is given to show what is regarded as a fair proportion, but the weight must be at least 125 pounds, except for cavalry, or when less is especially authorized by the Adjutant-General."

It will be observed that up to 5 feet 7 inches, the normal weight is taken to be 2 pounds to the inch, and for each inch above that height, 7 pounds are added, and that the chest girth at expiration is, for all heights above the minimum, just below half the height.

Grounds for Rejection.—The most frequent single cause for rejection is defective development; during 1898, more than a fourth of the rejections of candidates for the regular army were made on this ground. Second in order was defective vision; third, diseases of the circulation. Such is the order which commonly obtains also in the British army. Other causes, in order, were diseases of the genito-urinary organs, diseases of the digestive apparatus, bad character, general unfitness, deafness, and illiteracy. Men of defective development, if admitted, are noted for the time which they spend in the hospital and in the guard-house. During the early part of the Civil War, thousands of physically inefficient men were allowed to enter the army, only to be discharged after a few weeks' service, most of which was passed in the hospitals. Another element which it is most important to exclude is the habitually intemperate. As Dr. Tripler has said, "First in a mutiny and last in a battle, the intemperate soldier is at once an example of insubordination and a nuisance to his comrades."

Inasmuch as the ability to march is one of the prime qualifications of a soldier, particular attention is paid to the condition of the legs, ankles, and feet. The existence of enlarged veins of the ankle or thigh or back of the knee is sufficient cause for rejection. Large or recent bunions, and corns on the sole, flatfoot, and "hammer-toe" are disqualifications. Fœtid perspiration of the feet is an intolerable nuisance to others in close association, and is sufficient ground for exclusion.

The loss of many teeth or a condition of general decay indicates, as a rule, a lack of stamina. Moreover, the soldier in the field needs good teeth to chew his hard biscuit and not always tender meat. An insufficient number of opposed molars to insure proper mastication is sufficient ground for rejection. In 1898, in England, of 66,501 recruits for regular service, 1,767, or nearly 1 in 38, were rejected on account of bad teeth alone; but this figure gives no indication of the proportion of candidates who might have been rejected on that ground, since many were summarily rejected on other grounds without examination of the teeth.

Defective hearing, that is, inability to distinguish ordinary conversation with either ear at 50 feet, is a disqualification, since orders may be either not heard at all or misunderstood.

THE HYGIENE OF THE SOLDIER.

Personal cleanliness is of great importance in the maintenance of health and efficiency, and should be the subject of much attention on the part of inspecting officers. General bathing can hardly be expected in a large camp in the winter months, or at any time when water is scarce; but whatever the season, a small amount of water, a quart or so, applied with a wash-rag or sponge, and with soap, should be sufficient for a decent degree of cleanliness. In the warmer months, where water is plenty, full baths and swimming should be encouraged. During prolonged campaigns with limited opportunities for keeping the person and clothing clean, many men are disabled by chafing and ulcerations, following irritation of the skin by perspiration, dust and dirt, and contact with unwashed, hardened underclothes. Body lice always make their appearance, and add much to the discomfort, which is only temporarily relieved, but eventually augmented, by scratching with the nails. Infested, dirty men convey the evil by contiguity to their cleaner associates, who then suffer not only in body but in mind, filled with disgust and loathing, and longing to return to civil life.

Contentment and cheerfulness are very essential to the well-being of an army; discontent and ennui undermine health and discipline and, consequently, efficiency. In the continental armies, ennui, leading to homesickness, is believed to be a prime cause of the large number of suicides and cases of insanity. This is more marked with the infantry, which branch requires less time devoted to work. In all armies, it is recognized as leading to excessive use of tobacco and liquor, and to all manner of bad habits. On the march and in time of general activity, the mind is stimulated and needs no special diversion; but after a camp has been permanently established, and the men have settled down to the routine of camp life, they begin to fret, and soon seek solace in tobacco, alcohol, and gambling, and not infrequently in perversions of the generative function. Gambling is not only an unhealthy excitement, but engenders serious quarrels, bitterness and disappointment, and is commonly carried on in crowded quarters and foul air.

The ability to keep troops in camps contented is regarded as one of the strongest evidences of capacity for command and administration. To keep men occupied is not sufficient; the occupation should not be wholly routine drilling and marching, but interesting and pleasant work of other kinds, and entertainments largely of an amusing nature. Extra drills, known to the men to be unnecessary, and carried out only to keep them busy, do not relieve the situation, but add to the difficulty. The establishment of reading-rooms and opportunities for following mechanical trades are of much service. All men of experience testify to the great value of athletic sports, competitive target shooting, gardening for pleasure and profit, vocal and instrumental concerts, vaudeville and minstrel shows, theatricals, and, in fact, anything which will offer a change from the hum-drum of life. Very little things suffice to break the monotony of life in camps, just as in the country and at summer

hotels, where the arrival of the train or stage, or the passing of a strange carriage, is an event calling forth the deepest interest, and a new arrival a genuine excitement.

Clothing of the Soldier.

Since the primary object of clothing is the conserving of body heat in cold weather and protection from the direct heat of the sun, it is essential that that worn in any one kind of climate should be adapted to the necessities of that particular climate. It is obvious that the same uniform cannot be used in the Northwest and in the West Indies and the Philippine Islands, where the blue uniform, ordinarily used in our army, has been universally condemned on account of its weight. Therefore, the material should vary according to the nature and place of service. In choosing material for uniforms, the chief points to be borne in mind are the properties of heat conduction and heat absorption, permeability, and durability.

Wool is a poor conductor, and is not easily penetrated by cold winds; therefore, it is very suitable for cold climates, but is likely to be oppressive in the tropics. It absorbs water freely, being very hygroscopic, and thus it absorbs the perspiration and prevents it from evaporating directly from the surface of the skin and causing thereby loss of heat. The chief disadvantage of wool is the difficulty with which it is properly washed. When improperly washed, the fiber shrinks rapidly, and the fabric becomes smaller and much less soft and absorbent. During washing, woollen materials should never be rubbed or wrung. They should be placed in water containing a proper amount of soap in solution, and moved about freely, well rinsed in water containing no soap, and hung up to dry without wringing. The soap used should be of good quality, as free as possible from excess of alkali, which injures the woollen by acting upon the natural fat of the wool, which is largely cholesterin.

Cotton and Linen.—Both these articles are good heat conductors, but are non-absorbent of moisture. Both soak up moisture from the skin, and evaporation of this requires so much heat as sometimes to cause chilling of the body. Both are durable, and neither, particularly cotton, need be very expensive. For underclothing, both are much inferior to wool, which, being a poor heat conductor and a good absorbent of moisture, prevents rapid cooling of the body when it is in a condition of active perspiration after physical exercise. It is far more permeable, also, to air, which it holds in the spaces between the fibers, and which adds to its property of non-conduction.

Light woollen underclothing, therefore, is preferable to either cotton or linen. A very good material is what is commonly known as merino, a mixture of woollen and cotton, in which the cotton constitutes about a third. This combines, in a way, the advantages of both materials, and is a much more washable fabric than pure woollen.

Shoddy is a very inferior material, made of the fiber of old, used

woollen goods, mixed with fresh wool, with which it is woven. The manufacturers do not introduce any more fresh wool than is absolutely necessary.

Color.—The color of clothing has an important bearing, both physiologically and from a military point of view. Color influences the absorption of heat more than the nature of the material itself. White materials absorb least and black the most heat. The difference in absorptive power of different colors is shown in a marked degree by the fact that white cotton over a black surface will reduce the temperature in the sun more than 10 degrees F. Gray stands next to white, and blue next to black.

From a military point of view, color is important, since different colors vary in their conspicuousness, and, therefore, strategically, the one which stands forth the least in the landscape is the best. The most conspicuous color is red, next white, then black and other dark shades, light blue and light brown and gray; but, naturally, much depends on the background: thus, green would be inconspicuous against grass and other green vegetation, but would show very distinctly against bare soil, whereas the light brown of the ordinary khaki is the least conspicuous in the latter position. Color also influences the absorption of odors by materials in practically the same order in which it influences the absorption of heat; that is, black and the dark shades are most absorbent, and white the least.

Military dress coats are usually closely fitting, warm and oppressive, and interfere with proper expansion of the chest, through tightness. In active service in the field, they are not worn. Undress coats are usually loose, and are far more comfortable and adapted to muscular effort. The khaki suits, worn by our troops in the tropics, are stiff and heavy at first, but become softer and more pliable with repeated washing. They are sufficiently loose for all purposes of comfort.

Trousers are made sufficiently roomy in the seat, and reasonably tight about the waist, with an inner belt, as no suspenders are worn. The bottoms are cut narrow rather than with a "spring."

Gaiters and leggings are used for protecting the ankles and legs from dust and mud. They are made of brown cotton duck with lacings, and commonly are not well-fitting. When lined, as they sometimes are, with thin leather, they are likely to be uncomfortably hot. The puttee is made of a soft kind of cloth, in a strip 4 inches wide and 6 or 7 feet long. To one end, about 2 feet of strong tape are fastened. In applying the puttee, it is rolled up with the tape in the center of the roll. Two turns are wound over the top part of the ankle-boot and it is then wound spirally up the leg to a point below the knee, and the tape at the end is then continued spirally over the whole and fastened at the end. It is found to be more comfortable and more pliable than leggings, and does not blister the heels, which leggings sometimes do.

Head Covering.—The head covering is a very important article in the dress of a soldier. It should protect against cold, heat, rain, and

the burning sun. It should be light, durable, and comfortable, not too closely fitting nor pressing unduly anywhere. Leather helmets, worn in some armies abroad, and felt helmets formerly used in ours, are hot, heavy, and oppressive. The ordinary white helmet is conspicuous, but comfortable in the sun. The ordinary forage cap is flexible and serviceable, but is not sufficiently ventilated for hot-weather use. The campaign hat of drab felt with broad brim and high crown has been found to fill most of the requirements in the field. In Cuba and in our new possessions, it was found at first to be too heavy, but experience, especially during the rainy season, has shown that it has advantages not possessed by any other form of head covering.

In foreign armies, unnecessarily heavy helmets and other head coverings are used largely for purposes of display, but to a certain extent also as a protection against mechanical injury. In the matter of display, there can be no question that many of them fulfil their object admirably; but as a means of defence, helmets of heavy leather and metal, weighing from three to four pounds and more, would hardly seem to secure such an amount of protection as to compensate for the great discomfort and the waste of energy which their use entails. In hot climates, helmets of bamboo, provided with puggeries, are very largely used, being light and affording good protection from the sun.

Stockings.—Concerning stockings, a great divergence of opinion exists. Woollen stockings frequently cause the feet to perspire, even in cold weather; but they are much warmer, and hence more conducive to comfort than cotton at that time. Cotton is naturally more comfortable in summer, and, to many people, also in winter. In our army, both kinds are issued. Many regard thick woollen stockings as the best for walking, in all climates, and as a protection against foot-soreness; yet it is probable that many cases of sore feet are brought about by the excessive perspiration induced by them. Perhaps a happy mean is a thin woollen stocking or one of fine merino. It is important that the stocking should fit the foot properly, for an ill-fitting stocking, particularly one too long in the foot or too broad, gives rise to folds which cause excoriations and blisters.

Boots.—The value of well-fitting comfortable boots, permitting unobstructed action of the muscles and joints and free circulation of blood when walking for pleasure and exercise, is too well known to need extensive discussion. To the soldier, the importance of good boots is still greater, since, as has been said, an efficient army is one that can march well; and soldiers cannot march with crippled feet. Moreover, it happens frequently in time of war, that in an emergency which makes a man dependent upon his walking power for his own life and liberty or for the proper carrying out of his order, a good boot is his best friend.

The sole should be thick and generously broad, so as to project all round beyond the upper, but should not be too heavy. The heel should be broad, low, and flat. The boot should be square at the toe or slightly rounded on the outer side in accordance with the natural

outline of the foot, so as to allow the toes full play in walking. When placed side by side, the inner margins of each should nearly touch throughout the whole length from the end of the toe to the ball of the foot. The inside should nowhere have rough inner seams or projections, which may cause chafing and blistering. If treated to a liberal amount of oil or grease at frequent intervals, the leather will be made more supple and at the same time more impervious to water. A preparation, recommended by the late Professor Parkes, consists of a mixture of a half pound of shoemaker's dubbing in a half pint each of linseed oil and of a solution of India-rubber. Solution is effected by gentle heat, which should not be applied by naked flame, since the India-rubber solution, containing naphtha or ether, is exceedingly inflammable. This preparation is well rubbed into the leather and renewed at intervals of three months. This is said to be the best water-proofing material for leather.

Cavalry boots with long legs are not suited to walking, as they are likely to produce chafing. On account of the disadvantages attending their use on dismounted duty, they have, since 1902, been given up in all branches of the United States army.

Underclothing.—Undershirts should be of woollen or, better, of merino, since pure woollen is unbearable by many and because of the rapid deterioration which follows improper washing. The woollen undershirts issued at first to the troops in Cuba and the Philippines were complained of as causing much irritation of the skin from prickly heat. In the tropics, a light weight woollen undershirt is of the highest importance in the prevention of body chilling from evaporation of perspiration. Half cotton and half woollen or two-thirds cotton and one-third woollen are highly recommended as advantageous combinations.

The ordinary shirt of the soldier is made of flannel, with a collar and breast pockets. It is made fairly full and is very comfortable. Woodhull recommends the carrying of an extra shirt for wearing next the body, the two being worn alternately. "At the close of the day's work the worn shirt should be taken off, dried, stretched, well-beaten, and hung in the wind and sun. This should be done even when there is no change." Drawers, stockings, and trousers should be treated in the same manner. Drawers are necessary for cleanliness and warmth. They are made of the same material as undershirts. In many of the foreign armies, drawers are not issued, and men who desire them are obliged to furnish them at their own expense.

Abdominal Bands.—Abdominal protectors, either in the form of the well-known abdominal band or of small flannel aprons to be worn next the skin over the bowels, are regarded as very essential in preventing bowel troubles, which so commonly appear after abrupt changes in temperature; protectors are especially valuable in the tropics, where diarrhœal diseases should be prevented as much as possible, on account of their possible serious and fatal results. The abdominal band, commonly called also "cholera belt," encircles the whole of the lower part

of the body. The flannel apron protects only the anterior part, and is fastened with a tape around the waist.

The "kummerbund" is much preferred by many. This is a common article of dress among the natives of hot Eastern countries. It is a broad fold of cloth, wound tightly five or six times about the waist, for the protection of the lower part of the spine from the sun's rays, and to act as a support to the back and loins. It is made of silk or cotton, or a mixture of the two, in lengths of ten to fifteen feet and about twelve to eighteen inches in width. To put it on, one needs the assistance of a companion. It is folded once lengthwise, so that its breadth is reduced a half and its thickness doubled, and then, while stretched taut, one end is placed in position and held there, and the person turns the body round rapidly until the full length is wound off, when the end is carefully fastened, so that it may not work loose.

These protectives of the abdomen prevent the evaporation of perspiration and chilling of the abdomen; without them, diarrhœa is likely to be induced by slight causes.

Water-proof blankets of rubber or other material are very important as a protection against rain or soil moisture. When obliged to lie on damp ground, they are a great protection. In the tropics, at certain seasons, the rainfall is exceedingly heavy and makes the use of some form of water-proof overcoat necessary; but since these are very hot, it is important to obtain them of as light a material as possible without sacrificing lightness to durability. India-rubber itself cannot be worn habitually or for a long time, because of its causing great discomfort through retention of heat and perspiration. It is of much more value in the form of a blanket to spread on the ground than as an article of clothing. Cloth may be made waterproof by alternate dipping into solutions of aluminum sulphate and soap, or by thorough soaking in raw linseed oil and exposing to the sun until thoroughly dry.

Other articles issued during very cold weather for extra warmth include hoods, gloves, overshoes, and overcoats. The overcoats are unlined.

The Soldier's Exercise and Work.

Marching.—Since the most efficient army is that which has the greatest capacity to endure hardship, it follows that such an army can do the longest and best marching. While the civilian may regard daily walks of ten, fifteen, twenty, and more miles as no great strain on the system, the first-mentioned figure is accounted good average travelling for soldiers on a long march, and the second for short movements; but either of these figures may represent exceedingly good work by the best of men in some climates and seasons and over some roads, or by raw recruits in their first marches over the best of roads. This is not for a moment to be looked upon as evidence of

the civilian's superiority over the soldier as a walker, for the two perform the exercise under very different conditions.

The civilian, in the first place, walks alone or with a companion or two, at his own gait and according to his own will. He may vary his step and may rest at his pleasure; he carries no greater burden than a walking stick, and may suit himself in the matter of dress and in the manner of wearing it. The soldier, on the contrary, is one of a large body proceeding somewhat stiffly at a pace set by one in command and not alterable at will. He carries his arms, accoutrements, and all his belongings, and, perhaps, his rations for a number of days, and is hampered by straps and clothing which interfere with free circulation. He rests when ordered, may be halted, without resting, with annoying frequency, and may "march at ease" only when, in the judgment of the commanding officers, this is practicable. At one time, he is moving with exasperating slowness on account of obstacles ahead, and again, is hurrying to catch up with those gone before. Moreover, his marching ground is chosen for him, and his miles are either through dust or mud, for a soil so damp as to give off no dust is speedily converted to mud by the impress of many feet. Therefore it is, that the soldier's 10 miles represents much more physical exertion than the civilian's 20, and his 15 miles much more, all things considered, than 50 per cent. increase over his 10. Forced marches of 25 miles and longer are very exhausting, and cannot be kept up for more than a very short time.

One of the most notable instances of long distance marching in a few hours in recent times is that of the City of London Imperial Volunteers who, in South Africa, in August, 1900, covered 30 miles in 10 hours hoping, according to a despatch of Lord Roberts, to prevent General DeWet from crossing the Krugersdorp-Potchefstroom railway. The celebrated march of Lord Roberts from Kabul to Kandahar, in 1880, over very rough country, was performed in 23 days. The longest day's marches were 20 and 21 miles, and the average distance covered was nearly 17 miles.

Among the best known long marches are several by United States troops, who hold the record for long distance continuous marching. In 1859, for example, a regiment of infantry marched from Fort Leavenworth, Kansas, to a point in California, a distance of 1,800 miles in 190 days, 28 of which were given up to resting, so that in 162 days of actual marching, an average distance of a little more than 11 miles was traversed. In 1860, a portion of another regiment went from Camp Floyd, Utah, to Fort Buchanan, New Mexico, a distance of 1,000 miles in 140 days.

In the Franco-Prussian War of 1870, a company of French chasseurs marched, in very inclement weather, over an exceedingly difficult road, for 41 hours, with one rest of an hour, another of two and a half hours, and halts of 8 minutes in each of the marching hours. The exact distance marched is not known, but the instance is cited as one of exceptional endurance and hardship.

In our army, ordinary and quick marching call respectively for 90 and 120 steps of 30 inches each per minute, or slightly over 2.5 and 3.4 miles per hour. Double time, which is quickly exhausting, calls for 180 steps of 35 inches each per minute, the equivalent of nearly 6 miles per hour; it can be sustained for not longer than 2 miles by more than average good troops. With the weight carried, 30 inches per step is quite sufficient. In the French army, 2.5 miles per hour are considered good average marching, beginning with 120 steps per minute, increasing gradually to 125 and 135, and returning during the second half hour to the original rate. The English quick-step is the same as ours; the "double quick" is less than ours in length and frequency—33 inches, 175 to the minute. The German step is between 31 and 32 inches, and 114 to the minute; the Austrian and Italian, 29 inches, 120 to the minute; the Russian, 28 inches, 120 to the minute. From the above, it will be observed that in none of the great armies of the world is the marching rate equal to that of the active civilian when out for an exercise walk.

Every soldier is obliged to carry, besides his arms and accoutrements, certain necessary articles, the aggregate weight of which is variable, but always considerable. In the carrying of this weight, great care is necessary so to dispose it that it shall not be over-burdensome or detract from his efficiency. In all services, the reduction to a minimum of the weight to be carried is a matter of great importance, but the disposition of the weight is, perhaps, of greater importance, for considerable harm may be induced by interference with respiration and circulation by pressure from the necessary straps across the chest and under the arm-pits. Under favorable circumstances, his impedimenta, with the exception of arms and canteen, may be transported for him, the result being not only greater covering of ground with less strain, but great conservation of efficiency. In adjusting weight, care should be taken to avoid compression of the chest as much as possible and to equalize the distribution so as to avoid fatiguing any one set of muscles unduly.

The German infantry soldier is more heavily equipped than the British or American, the total load exceeding 70 pounds, of which his clothing, exclusive of the heavy polished leather hemlet, accounts for nearly 24 pounds, and his arms and equipments, filled water-bottle, and entrenching tools nearly 43 pounds, the remainder being rations and sundries. His kit is carried in a leather knapsack, around which his rolled overcoat is fastened, and to the back of which his camp kettle is strapped. The Russian soldier also carries more than 70 pounds; the Italian, about the same; the French, between 65 and 70, and the Austrian, about 60 pounds.

The blanket bag, which was substituted for the knapsack in our army in 1882 and abandoned after twenty years' use, is more oppressive than the blanket roll; but the blanket roll is also oppressive, since, being carried across the body from one shoulder, with the ends tied together, it impedes the movements of the chest. Morever, its use

involves a certain degree of inconvenience, since when the blanket itself is in use, the articles contained must be cared for in some other way. Other devices to take the place of blanket rolls and knapsacks are in use, and meet with different degrees of approval. The one most highly commended neither impedes respiration or circulation, nor involves contact with the back and consequent shutting out access of air. The weight is supported chiefly by the hips.

With new levies, the first marches should not exceed a very few miles, the distance being increased gradually day by day, until they become well seasoned, with occasional days, not including Sundays, set apart for rest and recreation. When thoroughly seasoned, there is less friction, and with greater experience, comes increased efficiency. It takes but a short time for new soldiers to learn not to attempt to carry unnecessary articles, which, at first, they are invariably prone to look upon as essential to comfort and pleasure.

Cavalry and infantry should march separately if possible, and in as open order as practicable, in order to avoid crowd-poisoning, which is a consequence not alone of indoor overcrowding, but also of close aggregation of men in the open air.

If possible, marching by night and in the hottest part of the day should be avoided, for in hot weather the men are easily exhausted by exercise in the blazing sun, and since they can get no sleep during the day, they need the night hours for their proper rest. The early morning hours are the best for marching, as for other forms of work, the men being then at their best; but unless absolutely necessary, their sleep should not be broken before the usual time, since what is thereby gained in distance is more than lost through the interruption of necessary sleep. Before starting, a light breakfast, including hot coffee, should be taken.

During the first hour, the pace should be fairly slow, and when two miles have been covered, there should be a halt of at least a quarter of an hour, during which the men should attend to calls of nature and throw off their loads and rest at full length. When the march is resumed, the distance to be covered may be lengthened by a half mile, and when this distance has been traversed, there should be another halt of about the same length as the first. After this, the rate may be increased to three miles per hour with a halt of ten minutes in each hour, and this rate is sufficiently fast, except for forced marches. The halt in the middle of the day for dinner should be of several hours' duration, so that the men may have a good rest, avoid heavy work directly after a hearty meal, and look after the condition of their feet. As it is unsafe to eat heartily or drink copiously while greatly fatigued or overheated, a reasonable interval should be allowed before dinner.

Halts due to accidental circumstances are very trying to patience and strength, and when their probable duration can be determined, this should be communicated down the column, in order that, if the interval is to be of sufficiently long duration, the men may have the

advantage of resting, rather than stand with their arms, losing patience and temper. Since, also, irregular rate of movement is fatiguing and annoying, minor obstacles, such as mud and water, should not be allowed to interfere with regular progress. Music of all kinds is very invigorating to marching men; band music, fife and drum, the drum alone, and singing. In the continental armies, singing is much encouraged, as it keeps up the spirits and gives a rhythm and swing to the march.

If the weather is hot, men should be allowed to promote evaporation of perspiration by opening their coats or blouses; otherwise, water is lost from the body without performing its function of reducing the body-heat. To avoid excessive thirst, a full drink of water should be taken before starting. The canteens should be filled with water or cold tea for use during the day; but free drinking on the march is not to be advised, since it tends to beget constant thirst. The mouth should be kept closed as much as possible during the march, and the sensation of thirst can be controlled by holding a smooth pebble in the mouth or chewing a green leaf. Simple occasional moistening of the mouth is better than free and frequent drinking.

In case of exhaustion by excessive loss of fluid by perspiration, drinking on the march is necessary; but under the usual conditions, the canteen should be used only at meals and near or at the end of the day's march. Another reason for abstaining as much as possible from drinking is the uncertainty of supply, for no dependence can be placed on the probability of refilling the canteen during the day's march. Hence, each man should conserve his supply as though he were certain that no more is to be had before the day's destination is reached. The amount carried may be kept fairly cool by wrapping the canteen in a wet cloth, the evaporation from which causes perceptible lowering of temperature. A little vinegar or lime juice, if obtainable, added to the water, gives it a relish and helps to allay thirst.

"In many parts of the West, water is so scarce that judicious management is required to forward troops over the route. Some camping-stations having only enough for one or two companies, the command, if larger, must pass in detachments. Or it may happen that the distance between the nearest water-supplied sites is too great to be marched without rest, in which case a dry camp must be formed at some intervening point. The passage of the Gila Bend Desert, 35 or 40 miles from water to water, is usually effected by making a night march of 25 miles, when the troops go into camp to rest for a few hours before resuming their journey, and to have coffee issued from a water-supply carried in the wagons." (Smart.[1]) On arriving at a camping-place, the water supply should be immediately guarded to prevent pollution and trampling of the margin. If the supply is small, the guard should be doubly efficient. If the supply presented is a small and shallow stream, it may be well to make small reservoirs by means of temporary dams, one for drinking-water for the

[1] Buck's Hygiene and Public Health, New York, 1879, Vol. II., p. 119.

men, another below for the horses, and another for bathing and laundry purposes.

Straggling should be prevented as much as possible, since it is a very serious evil to the morale and efficiency of the body as a whole. If straggling becomes considerable, the column should be halted until the stragglers can overtake it, else they will get no rest, since the hourly intervals for rest must be utilized by them in coming up, and the column is, perhaps, already in motion again. Those claiming to be sick or unable to march should be examined by the medical officers, who will separate the really unfit from the malingerers; the former are given careful transportation; the latter, disposed of according to their deserts.

At the end of a day's marching, the men should be dismissed as soon as possible, and they should be careful to guard against becoming chilled through reckless removal of clothing, and should again look after the condition of their feet and persons.

On long marches, an occasional day should be taken for complete rest and recuperation, otherwise an inevitable diminution in efficiency will be occasioned. Woodhull cites an interesting instance of overmarching in the Franco-Prussian War. The German Garde-Corps, consisting of 30,000 infantry, left the Rhine on August 3d, lost less than 9,000 in action, and on September 2d, the day after Sedan, numbered 13,000 for duty. On September 19th, they reached Paris with but 9,000 men, more than 11,000 having been broken down by exertion, little actual sickness having occurred.

Care of the Feet on the March.—If good marchers make the best soldiers, it follows that the possession of the best soldiers is largely dependent upon the condition of the feet, and, therefore, it is incumbent on the line officers and medical corps to see that the individual men are properly instructed in their care, and that they are faithful in performance. The footsore man, so far as efficiency is concerned, is a sick man and becomes the equivalent of baggage. He cannot march, and suffers pain when at rest. Nearly all new men not accustomed to marching are likely to suffer from excoriations across the toes, on the insteps and malleoli, and on the back and sides of the heels. This is due to friction, and, if attended to at once, may be prevented from becoming serious.

The application of strips of adhesive plaster of generous size to the affected parts will afford the same protection as is given by a leather glove to the hand engaged in any frictional work. Blisters should not be opened, except by a minute puncture at the edge; after the fluid has oozed away, the spot should be protected with adhesive plaster. The extensive opening of a blister permits access of air to the sore area beneath, and the stimulation therefrom is very active and painful. Men should be instructed to trim their toenails square across and not too close.

Before marching is begun, all men with any soreness of the feet should report themselves and be examined, and at the end of the day,

if not before, they should be regularly inspected. Men unused to marching will often find greasing or soaping the feet and stockings an excellent prophylactic against soreness. A neutral grease like mutton-tallow is preferable to soap, since sometimes it happens that the latter assists the perspiration in macerating the cuticle. If the boots are made supple with grease, they tend less to cause soreness, and, in addition, are rendered waterproof. An excellent plan for officers and others who can afford them, is to wear silk stockings under the ordinary socks, especially when the feet are naturally tender. The feet may be toughened by being soaked in warm strong solutions of alum or common salt. Zinc ointment, containing 5 per cent. of tannin, is also very useful. Salicylated talc (talc 87, starch 10, salicylic acid 3 parts by weight) is used in the German army both on the march and in garrison. It is sifted from a dredging-box into the shoes and over the feet.

If the soreness is due to the stockings and not to the shoe, it is often advantageous to change them from one foot to the other, or to put them on inside out. Some of the continental armies use bandages in place of stockings, and some use neither, substituting therefor a liberal coating of grease. Soreness is due often to neglected bunions, corns, both hard and soft, and infleshed nails. These troubles need special treatment. In the British army, the authorities have caused a number of the non-commissioned officers to be instructed in chiropody, and the success of the experiment has made it probable that a permanent corps of trained chiropodists will be established for the infantry.

During the long halt at midday, each man should remove his shoes and stockings, and, if water is to be had in abundance, he should remove the acrid perspiration and dirt from his feet by thorough washing, paying particular attention to the surfaces between the toes, where excoriations and soft corns are prone to appear. Dusting-powder or zinc ointment on absorbent cotton may be applied, if advisable, between the toes. The feet should be made quite dry before the stockings are again drawn on. If water cannot be obtained in sufficient amount, wiping with a dry or moist cloth will be found to add materially to comfort, and is much to be preferred to long soaking, which, by softening the cuticle, assists the formation of blisters. At the end of the day, the feet should be washed and the stockings changed; those removed should be washed as soon as practicable and dried during the night.

Care of Other Parts.—Not uncommonly, soldiers, especially raw recruits, are much inconvenienced and annoyed by chafing at various points, particularly on the inside of the thighs and between the nates. This is promoted by perspiration and restrained by dusting-powder, zinc ointment, vaseline, and cleanliness. Woodhull advises against washing the face and neck in the morning while on the march, because the removal of the natural secretion makes the skin more susceptible to the influence of heat and dust. He recommends washing the eyes and mouth, and merely wiping the face and neck with a damp cloth. At night, the face, neck, and whole body should be washed, if possible;

but, foremost of all, the head, armpits, feet, and genitals and adjacent parts.

Care should be taken that the bowels are not neglected while on the march, any more than while in garrison. If purgatives are required, those given should be mild in character, and not such as may require repeated operations at short intervals.

The Soldier's Food; "Rations."

The word "ration" is understood commonly to mean the amount of food issued to each soldier for a single meal. This, however, is far from being the truth. Under the regulations, "a ration is the allowance for sustenance of one person for one day, and consists of the meat, the bread, the vegetables, the coffee and sugar, the seasoning, and the soap and candle components." Enlisted men and hospital matrons, and, when the circumstances of their service make it necessary, civilians employed by the army, each draw one ration each day. The ration is not necessarily the diet, since parts of it may be exchanged for other things or for the cash equivalent with which to buy them. It is fixed by law, and can be changed only by legislative enactment.

The different articles composing the ration for troops in garrison or in permanent camps, excepting in Alaska, and their amounts, are as follows:

Articles.	Quantities.
Meat Components.	Ounces.
Fresh beef	20
or Fresh mutton when the cost does not exceed that of beef	20
or Bacon	12
or Canned meat, when fresh meat is not available	16
or Dried fish	14
or Pickled fish	18
or Canned fish	16
Bread Components.	
Flour	18
or Soft bread	18
or Hard bread	16
or Corn meal	20
Vegetable Components.	
Beans	$2\frac{2}{5}$
or Peas	$2\frac{2}{5}$
or Rice	$1\frac{3}{5}$
or Hominy	$1\frac{3}{5}$
Potatoes	16
or Potatoes $12\frac{4}{5}$ and Onions $3\frac{1}{5}$	16
or Potatoes $12\frac{4}{5}$ and canned tomatoes $3\frac{1}{5}$	16
or Potatoes $11\frac{1}{5}$ and other fresh (not canned) vegetables when obtainable $4\frac{4}{5}$, or desiccated vegetables (when fresh vegetables cannot be furnished) $2\frac{2}{5}$.	
Fruit Components.	
Dried or evaporated prunes, apples or peaches $1\frac{3}{5}$ (when practicable, 30 per cent. of the issue to be prunes).	

ARTICLES.	QUANTITIES.
Coffee and Sugar Components.	Ounces.
Coffee, green	$1\frac{3}{5}$
or roasted	$1\frac{7}{25}$
or Tea, green or black	$\frac{8}{25}$
Sugar	$3\frac{1}{5}$
Seasoning Components.	
Vinegar (gills)	$\frac{8}{25}$
or Vinegar $\frac{4}{25}$ gill and Cucumber pickles $\frac{4}{25}$ gill	
Salt	$\frac{16}{25}$
Pepper, black	$\frac{1}{25}$

The ration issued to troops in the field in active campaign is the same in amount, but is somewhat less elastic. Thus, the various forms of fish are eliminated, as also are peas and hominy, and when potatoes are not procurable locally the desiccated form is served. The fruit component consists of canned jam ($1\frac{2}{5}$ ounces).

What is known as the "travel ration" is issued in place of the ordinary ration "when troops travel otherwise than by marching, or when for short periods they are separated from cooking facilities and do not carry cooked rations." It consists of the following articles and is issued in the amounts stated, per hundred rations:

Articles.	Pounds per 100 rations.
Soft bread	112.5
or Hard bread	100
Canned corned beef or corned-beef hash	75
Baked beans	25
Canned tomatoes	50
Coffee, roasted, pounds	8
Sugar	15

On arrival at their destination, the ordinary ration is resumed. When travelling unaccompained by an officer, each man may be allowed a cash sum per day for the purchase of liquid coffee in place of the coffee and sugar portion of the travel ration.

The "emergency ration" consists of three $1\frac{1}{3}$-ounce cakes made of equal parts of pure chocolate and pure sugar; three 4-ounce cakes made of a compound of 1 part of flour made from dried lean meat and 2 parts of parched ground wheat, with seasoning of salt; $\frac{3}{4}$ ounce of fine salt and 1 gram of black pepper. Each complete ration is contained in a separate tin box, which may be opened only by direct orders from an officer or in case of extremity. Of this, as many days' rations are issued at once as may seem necessary. Abroad, the well-known pea sausage, consisting of pea flour and fat pork, is much used in the emergency ration. This, mixed with hot water, makes a very good soup, but soon proves to be cloying. Meat biscuits and dried meats also are much used.

It will be observed that the ordinary ration is fairly flexible as it stands, but it may be made more so by exchanging articles not wanted. It is established by law, but is not necessarily the daily dietary. Thus,

the various articles (excepting the fresh vegetables, bread, and baking-powder) not needed for consumption may be purchased by the commissary as savings at the invoice prices. "Savings and sales of fresh beef (except of that issued for the sick in hospital, the detachment of the hospital corps, and the hospital matron serving therein) are prohibited,"[1] but the fresh meat allowance may be reduced in amount and its money value drawn in other things. For each ration of flour turned in, the company is entitled to one ration of bread or the price of one flour ration.

In many permanent camps, gardens may be cultivated and a supply of fresh vegetables thus obtained both for immediate and future use. Commutation for these is allowed at the prices of potatoes and onions in the vicinity or in the market from which supplies are derived, in the proportion of 80 per cent. of potatoes and 20 per cent. of onions. The amounts of money from all sources form the company fund, which is disbursed by the company commander solely for the benefit of his own men.

Fruits and vegetables are very essential in the dietary, on account of their antiscorbutic properties. The most valuable of the antiscorbutics is held commonly to be lime juice; the juice from the fresh limes is superior to the bottled article. Lemons are of about the same value as limes. Among vegetables, potatoes, onions, and cabbage take high rank. The legumes are devoid of antiscorbutic properties. According to Woodhull, the best antiscorbutic is the agave. "To prepare it, cut off the leaves close to the root, cook them well in hot ashes, express the juice, and drink, raw or sweetened, 1–4 wineglassfuls three times a day. The white interior of the leaves may be eaten." The dried vegetables and fruit are less valuable than the fresh, and should be allowed to supersede the latter only when these cannot be obtained, but they are far superior to compressed vegetables, which, in the process of compression, lose much of their salts and a portion of their proteids. Dried vegetables should be soaked well in water before use, else they may cause digestive disturbance and diarrhœa.

Alcohol in the Ration.—The question of the advisability of including a spirit allowance in the ration has been the subject of much careful consideration in all countries, and has been answered with practical unanimity in the negative. But there are times when a single issue of spirits, or repeated issues according to circumstances, may be useful and even necessary. Thus, on a forced march, when exhaustion is great, a stimulant may be of very great necessity, although it is said that hot tea, if time admits of its preparation, may be equally or still more serviceable. When given at all, spirits should be taken well diluted, and never in concentrated form.

During the Civil War, a daily issue of a gill of whiskey to each officer and man of the Army of the Potomac was ordered, half to be given out in the morning and half in the evening. This was brought

[1] Army Regulations, p. 180.

about by the fact that for several weeks the men had been subjected to unusual hardships and extra duty, and were breaking down under the strain. The issue, which was to continue "until further orders," was greeted with enthusiastic appreciation of the farsightedness of the authorities responsible for it. "Until further orders" proved to be exactly one month, and hot coffee was substituted for the whiskey, the issue of which was ordered to be "*immediately discontinued.*" During the month, the general condition of health of the troops was not only in no way improved, but became markedly worse, while drunkenness, with its attendant evils, became much more common.

Concerning the use of beer and light wines, a very different opinion is held by many of those best qualified to judge by results observed. In several of the great armies of Europe, an allowance of light wine is customary, and it seems reasonable to suppose that where the importance of a large standing army is so great, alcohol in this form would not be issued, were it not upon the belief, based on long experience, that, directly or indirectly, it is a benefit, and not an evil. A little light wine at the close of a day of hard work, but not before or during its performance, appears to be recuperative and restful, either in the usual strength or diluted with water. In this country, the so-called canteen system is believed to have been productive of a distinct gain for *temperance* among the soldiers; and by temperance is not meant total abstinence.

The canteen is a place at a military post where small wares, little luxuries, tobacco, and the lighter alcoholic drinks may be purchased under close supervision, so that abuses cannot occur. There is no inducement held out for the men to buy drink, and what is sold must be consumed on the premises. What small profit is derived goes to the post exchange, which, besides the canteen, comprises a general store, a lunch counter, recreation rooms supplied with reading matter, and a gymnasium.

It is believed that the canteen system, before its abolishment, had worked out the solution of much of the problem concerning drunkenness in our army. The soldier accustomed in civil life to the use of beer was enabled to obtain it in a decent way and only to a reasonable extent, and hence had no temptation to seek alcohol in, perhaps, stronger forms elsewhere and not under supervision. He was more likely to remain habitually sober, instead of being occasionally helplessly drunk and commonly in difficulties. It is said that the order of things that obtained on pay day under the old system had been very largely abolished. Then, pay day was a source of satisfaction to nobody but the saloon-keepers, who sold bad liquor at high rates; men were absent days at a time without leave; courts-martial were busy, and there was much guard-house service. Those who have studied the matter, regard the canteen as the friend of decency and discipline, and the enemy of every saloon near a garrison. Naturally, the saloon-keepers and that class of reformers who believe in the possibility of bringing about radical changes in human nature by legislation, became

violently opposed to the continuance of the system; and, indeed, the latter were so successful in their agitation against it that, in spite of the practical unanimity of the officers of the army of all grades in its favor, it was abolished by Act of Congress in January, 1901.

Preparation of Food.—The art of cooking is a very valuable accomplishment of a soldier, especially when on active service. In camps, cooking is done by persons enlisted for that purpose, one cook being allowed by law for each company, troop, or battery. On application, he must first pass the regular examination of a recruit, and then one in which he must demonstrate his knowledge of methods and skill in caring for, preparing, and serving food. Kitchens are placed under the immediate charge of non-commissioned officers, who are held responsible for their condition and for the proper use of rations. Only those employed or those on duty are allowed to visit or remain in the kitchens. The general supervision of the cooking and messing devolves upon the company commanders, who are charged to exercise personal care and judgment to prevent waste and nuisance, and to see "that suitable men in sufficient numbers are fully instructed in managing and cooking the ration of the field," since when the conveniences for cooking on a large scale are not at hand, it becomes necessary for men to divide into small squads and prepare their own meals.

The baking of bread is carried on in post bakeries, under the charge of enlisted men detailed as chief and assistant bakers. Baking by companies at posts is expressly prohibited, but is the rule in temporary camps and with marching columns, portable ovens of various kinds and barrel ovens being employed. The barrel oven is best made with a barrel with iron hoops, which is placed on its side, covered completely with clay or stiff mud, except at its open end, and then with a thick layer of dry earth, leaving, however, a small (3-inch) opening at the top of the inner end to serve as a flue. A fire is made in the barrel and kept up until all the wood is burned, leaving an oven of clay, for which the hoops act as a support.

In the field, on account of transportation, it is necessary that cooking appliances should be as simple and economical of space as possible. The greater the amount of baggage, the greater the number of wagons necessary; the greater the number of wagons, the greater the number of animals and the greater the amount of necessary forage.

Is the U. S. Ration Adequate in Amount and Composition?—This question has agitated the minds of many during recent times, and, more particularly, since the outbreak of the war with Spain, and the ration has been denounced, whether justly or unjustly, in respect to both quantity and quality. For a better understanding of the subject, a comparison of the official ration with those of other countries in which warfare is a larger industry than with us may not be amiss.

The British soldier receives, on home service, 12 ounces of meat and 1 pound of bread, and obtains what he can of vegetables and groceries from a *per diem* allowance of 7 cents, which is deducted from his pay. What he needs in addition, he buys at the canteen (at cost)

or elsewhere. In the field, he receives 1 pound of fresh, salted, or preserved meat, or, when the supply of cattle is abundant, 1.25 pounds of fresh meat; 1.25 pounds of fresh bread, or 1 pound of buscuit, or 1 pound of flour or meal; $\frac{1}{3}$ ounce of coffee and $\frac{1}{6}$ ounce of tea, or a double allowance of either, or $\frac{1}{3}$ ounce of chocolate or cocoa; 2 ounces of sugar, $\frac{1}{2}$ ounce of salt, $\frac{1}{36}$ ounce of pepper; 1 ounce of compressed vegetables, or $\frac{1}{2}$ pound of potatoes or other fresh vegetables, or 2 ounces of split peas, or $\frac{1}{4}$ pound of onions, or 2 ounces of rice; $\frac{1}{10}$ gill of lime juice with $\frac{1}{4}$ ounce of sugar when fresh vegetables are not issued or when the medical officer thinks necessary; $\frac{1}{2}$ gill of spirits, when considered necessary, besides tobacco, light, and fuel. This ration is subject to change for better or worse, according to circumstances.

The French soldier receives 10.6 ounces of meat, 26.4 ounces of munition bread and 8.8 ounces of white bread for soup, or 19.4 ounces of hard bread; 3.5 ounces each of dried vegetables, chiefly beans, and fresh vegetables, with salt and pepper. Much of this comes out of his pay.

The German soldier receives in time of peace, according as he is in garrison or in camp and field manœuvres, 5.30–17.65 ounces of meat, or 4.40–6.00 ounces of bacon; 26.50–35.30 ounces of bread, 3.18–6.00 ounces of rice, or 4.25–6.00 of groats, or 8.10–12 of peas or beans, or 53.00–71.00 of potatoes; and in camp or field manœuvres, a liter of beer, or a half liter of wine, or a tenth liter of spirits, and 1.75 ounces of butter. In time of war, he receives 13.25 ounces of fresh or salted meat, or 8.80 ounces of smoked meat or sausage, 26.50 ounces of bread, 4.40 ounces of rice or groats, or 8.80 of peas, beans, or flour, or 53.00 ounces of potatoes, 0.90 ounce of roasted or 1 ounce of raw coffee, and 0.90 ounce of salt.

The Russian soldier, in time of peace, receives 7.25 ounces of meat, 43.35 of rye bread or 28.9 of biscuit, 32.65 of flour, and 4.80 of groats. In time of war, he receives, according to whether he is on the smaller or larger war ration, 14.45–21.65 ounces of meat, 36.15 of rye bread, 4.80 of groats, and 1.35–2.70 of suet or butter. He is allowed also money for 1.50 ounces extra of meat, and an additional cent and a half for vegetables and other articles.

The Austrian soldier receives in peace 6.70 ounces of meat, 30.90 of bread or 17.65 of hard bread; 6.60 of flour, or 2.50 of peas or beans, or 4.95 of groats, or 5.30 of millet, or 4.00 of barley, or 3.70 of rice, or 19.75 of potatoes; 5.55 of sauer kraut, and 0.60 of suet. In time of war, 9.90 ounces of meat or 6.00 of salted meat or bacon; 25.20 of flour, 3.50 of hard bread, 5.30 of peas, or 4.94 of groats, or 5.55 of sauer kraut, or 8.80 of potatoes; and 1.05 of suet, with coffee, and beer, wine or spirits, and 4 cents for extra vegetables.

The Spanish soldier receives 24 ounces of bread, and is required to spend 7 cents out of his daily pay of 9 cents for the rest of his subsistence. In time of war, his pay is increased from 2.5 to 5 cents per day.

The Italian soldier receives 7.05–10.60 ounces of meat, 0.50 of bacon, 32.40 of bread, 5.30 of rice, 0.70 of sugar, 0.50 of coffee, 0.50 of salt, and a quarter liter of wine.

Comparison of these figures with those of our own ration, demonstrates at once that ours is in all respects the most liberal ration in the world. In only one instance is there a conspicuous superiority in the amount of an important constituent; namely, the very generous allowance of potatoes in the German ration. Not only is the U. S. ration the most abundant, but it admits of greater variety than any other. But even at that, it is held by many to be insufficient in amount for the proper performance of the work a soldier may be called upon to perform. Experts in the making of dietaries have proposed increasing the flour and soft bread allowance by about a fourth, and adding about 5 ounces of flour to the alternative allowance of hard bread and 20 per cent. to the alternative allowance of corn meal, with a reduction of 40 per cent. in the allowance of potatoes, and the alternative of money value in milk or cheese in place of the allowance of peas or beans.

In the consideration of the question of quality and variety, it should be borne in mind that, while it is necessary to have a standard of food value fixed by law, it is not necessary to consume precisely the articles named. Nor is it possible to fix a money value to the ration, and give out the cash equivalent in place of actual food, for the soldier is not always near a market, and, moreover, if he were, it is most evident that the same amount of money in different places would yield very different amounts of nutriment, since in one, the food supply is abundant and cheap, and, in another, scanty and expensive. What the soldier eats, depends upon circumstances, and largely upon the discretion of company commanders guided by the advice of the medical officers, but, as said before, the actual food value is fixed by Congress, and is based on the experience and study of many years.

Is the United States Ration Suited to the Tropics?—The question of the suitability of our ration to the tropics is one which has assumed great importance since the necessity arose for maintaining large armies in our new possessions, and its discussion has been marked by a much more temperate tone, and has, therefore, yielded better results. The beginning of the discussion may be said to have arisen from the fact that it became generally understood that bacon was a necessary constituent of the daily food, both in camp and in active operations, instead of an alternative, as may be gathered from the wording of the statute—fresh beef, *or* fresh mutton, etc., *or* pork, *or* bacon, *or* salt beef, *or* dried fish, *or* pickled fish, *or* fresh fish. Bacon has its advantages at certain times, but is not eagerly sought after by those not in good health, nor is it acceptable in very hot climates as a regular diet any more than any other fatty food. Fats are much needed in cold climates for the production of heat; in hot climates, the necessity for their use is but slight in comparison. But when fresh meat cannot be obtained either on the hoof or from cold storage, and when the appetite is cloyed by canned meats (and this is soon brought about), bacon is acceptable as an occasional substitute.

To those at a distance and unacquainted with local conditions, the ideal supply of fresh meat is cattle on the hoof. But the cattle of the

tropics are not the same as those which we know, nor are they always to be had in even small numbers. Sending live cattle from home, to be driven along on the march to be killed as needed, is not always practicable, for even if landed in good condition, they cannot be kept on the march, and, unless the country traversed is good grazing land, they lose weight and die off rapidly. Canned meats are much inferior to fresh meats, and cannot long be eaten with relish. The canned so-called *roast* beef is commonly the residue of meat after the extractives have been boiled out of it for the manufacture of meat extract, and it is, therefore, lacking in flavor, although not materially diminished in nutritive properties. It is often as tasteless and almost as difficult to chew as towelling, and is far from inviting in appearance, especially when the cans are opened at ordinary hot summer temperature.

According to many experienced minds, the consumption of meat in any form should be much limited in the tropics. Roquemaure[1] advises the European in the tropics to take nothing into his stomach, except articles easily digested; mutton, beef, and pork only in moderation, and not too thoroughly cooked, and not regularly or too often; birds, eggs, and fish are more to be commended; especially to be relied upon are rice, dried vegetables, fresh vegetables, starchy foods, and ripe fruits in good condition. Kohlbrügge[2] places above all other influences in the deterioration of Europeans in the tropics the too extensive use of animal fats, which, he claims, are responsible for much of the diarrhœal troubles of the tropics. He recommends the vegetable oils for supplying what fats are needed by the body.

The observations of Dr. L. L. Seaman,[3] in Porto Rico, lead, in part, to the same conclusion. He relates that, within a week after landing in the summer of 1898, in spite of the strictest sanitary precautions and personal hygiene, the entire force with which he was connected suffered from some form of intestinal catarrh from one cause and another, and that medication was of no avail, since the diet of bacon, salted beef, canned beans and pork, and hardtack proved to be a continual irritant, by which the troubles were aggravated and the power of resistance much reduced. Under such conditions, malaria and typhoid fever gained a foothold in the system with much ease; first came the malarial fevers of the various types, and, in the early part of September, on the introduction of the germs from Tampa and Chickamauga, typhoid fever broke out, and, spread by flies, continued with varying severity until embarkation for home in November. The value of a milk-diet was emphatically demonstrated.

Koerfer's[4] recommendation to Europeans, to leave their pork fat, meats, and alcohol at home with their heating stoves and furs, when they go to reside in the tropics, is quoted in confirmation.

While the use of green vegetables is universally recommended in

[1] Hygiène alimentaire aux pays chauds, Bordeaux, 1895.
[2] Die Acclimatisation der Europäer in den Tropen: Deutsche medicinische Wochenschrift, 1898, Nos. 27 and 28.
[3] New York Medical Journal, March 18 and 25, 1899.
[4] Deutsche medicinische Wochenschrift, July, 1898.

the tropics, it is not always easy, and, in fact, it is often extremely difficult or impossible, to obtain them, since the natives of the tropics are commonly content to live on rice, dried beans, and fruit, with an occasional taste of fish or meat. Canned vegetables, while grateful to the system, are not wholly to be recommended, on account of transportation. A can of string beans, for example, contains a maximum of water and a minimum of nutriment, and for its real service in the dietary may be said to be hardly worth its cost of carriage. Dried vegetables and fruits are more economical, but should be well soaked before use.

The Court of Inquiry, appointed to investigate the food supply of the army during the war with Spain, reported among other conclusions the following: "As to the effects of the food supply, having regard to sufficiency and quality, it seems to be clearly established that the army ration as supplied, without modification, to the troops serving in the West Indies was by no means well adapted for use in a tropical climate. If this be true, the unfitness of the ration should have manifested itself by its failure to keep the troops, who subsisted upon it, in the best possible condition for service in hot climates. This, in the opinion of the court, is fully established in evidence." Seaman advocates a reduction in the meat components, the use of salted meats not oftener than twice per week, and an increase in the allowance of vegetable and farinaceous foods and dried fruits.

Dr. Edward L. Munson, U. S. A.,[1] has studied the subject of tropical diet from the standpoints of physiological science, availability, and practicability, and concludes that the articles of the ration are correct as they stand, being admirably selected and of good variety, but need some rearrangement in their respective amounts. He proposes certain modifications, and offers four dietaries, the average of which is not widely variant from a proposed nutritive standard for soldiers in the tropics, as follows: Protein, 100 grammes; carbohydrates, 650; fats, 65. (Nitrogen, 16; total carbon, 392; fuel value, 3,491 calories.) Dietary I. contains the greatest amount of food material which may be drawn by the soldier:

TROPICAL DIETARY I.

Articles.	Quantity, ounces.	Fats, grams.	Carbohydrates, grams.	Protein, grams.	Nitrogen, grams.	Fuel value, calories.
Fresh beef	10	44.75	. . .	41.68	6.67	590
Flour	18	5.60	380.46	55.08	7.90	1,850
Beans	2.4	1.22	40.18	15.16	2.42	240
Potatoes	16	0.45	81.70	9.50	1.52	380
Dried fruit	3	1.53	33.80	1.77	0.27	220
Sugar	3.5	. .	94.25	. .	. .	397
Total	52.9	53.55	630.39	123.19	18.78	3,677

Total carbon, 395.14 grams; nitrogen to carbon, 1 : 19.6.

[1] The Ideal Ration for an Army in the Tropics. (Prize essay.) Boston Medical and Surgical Journal, May 3, 10, 17, and 24, 1900.

Dietary II. is especially applicable to field service; in this, the fatty constituents attain their maximum and the potential energy is high:

TROPICAL DIETARY II.

Articles.	Quantity, ounces.	Fats, grams.	Carbohydrates, grams.	Protein, grams.	Nitrogen, grams.	Fuel value, calories.
Bacon	6	105.06	. . .	15.64	2.49	1,042
Hard bread	18	6.63	371.81	73.12	11.74	1,926
Beans	2.4	1.22	40.18	15.16	2.42	240
Dried fruit	3	1.53	50.70	1.77	0.27	220
Sugar	3.5	. . .	94.25	. .	. .	397
Total	32.9	114.44	556.94	105.69	16.92	3,825

Total carbon, 328.76 grams; nitrogen to carbon, 1 : 23.

Dietary III. is proposed for garrison duty:

TROPICAL DIETARY III.

Articles.	Quantity, ounces.	Fats, grams.	Carbohydrates, grams.	Protein, grams.	Nitrogen, grams.	Fuel value, calories.
Fresh beef	10	44.75	. . .	41.68	6.67	590
Soft bread	20	6.80	299.20	53.83	8.61	1,506
Potatoes and onions	16	0.72	73.09	8.60	1.40	340
Dried fruit	3	1.53	50.70	1.77	0.27	220
Sugar	3.5	. .	94.25	. .	. .	397
Total	52.5	53.80	517.24	105.88	16.95	3,053

Total carbon, 328.76 grams; nitrogen to carbon, 1 : 18.

Dietary IV. is a combination of the several articles of the ration most closely approaching in character the food materials used by the natives of the tropics, proportioned according to the proposed standard:

TROPICAL DIETARY IV.

Articles.	Quantity, ounces.	Fats, grams.	Carbohydrates, grams.	Protein, grams.	Nitrogen, grams.	Fuel value, calories.
Fresh fish (cod), whole	14	0.79	. . .	31.73	5.07	120
Soft bread	20	6.80	299.20	53.83	8.61	1,506
Rice	4	0.45	88.87	8.75	1.40	407
Potatoes and tomatoes	16	0.54	65.80	8.17	1.36	297
Dried fruit	3	1.53	50.70	1.77	0.27	220
Sugar	3.5	. .	94.25	. .	. .	341
Total[1]	64.5	10.11	598.82	104.25	16.71	2,947

Total carbon, 327.50 grams; nitrogen to carbon, 1 : 19.6.

[1] It will be noticed that the first and sixth columns do not add up according to the totals expressed. The latter, however, being used in the table below, are retained unchanged.

The following table shows the mean nutrient composition of the four dietaries, and admits of ready comparison of one with another :

Dietary.	Quantity, ounces.	Fats, grams.	Carhohydrates, grams.	Protein, grams.	Nitrogen, grams.	Fuel value, calories.
No. I.	52.9	53.55	630.39	123.19	18.78	3,677
No. II.	32.9	114.44	556.94	105.69	16.92	3,825
No. III.	52.5	53.80	517.24	105.88	16.95	3,053
No. IV.	64.5	10.11	598.82	104.25	16.71	2,947
Average	50.7	57.97	575.85	109.75	17.34	3,375
Total carbon, 350 grams; nitrogen to carbon, 1 : 20.						

Posts and Camps.

Posts are permanent camps or those of position, and **camps**, in the usual sense, are temporary or incidental. At posts, the troops are housed in barracks, while at temporary camps they occupy tents and huts. The same sanitary considerations apply equally well to both, but choice of location of temporary camps in time of war is determined commonly by immediate and strategical considerations. Both should be laid out in such a manner as to insure proper air supply, cleanliness, and general salubrity, and should be as compact as is consistent with the principles of hygiene, for a compact camp is more easily cared for and defended, while one unnecessarily extended involves increased labor, slower delivery of orders and supplies, and greater difficulties in sanitary policing. With the tactical and strategical requirements and general plan, which is a matter of regulation, the hygienist has nothing to do, and his interest lies only in the distances between different bodies of men, the size of company areas, the cubic space per man, the proper location of sinks, latrines, and urinals, the measures adopted for surface drainage, disposal of sewage, garbage and stable manure, the water-supply, and other matters having a bearing on the health of the troops.

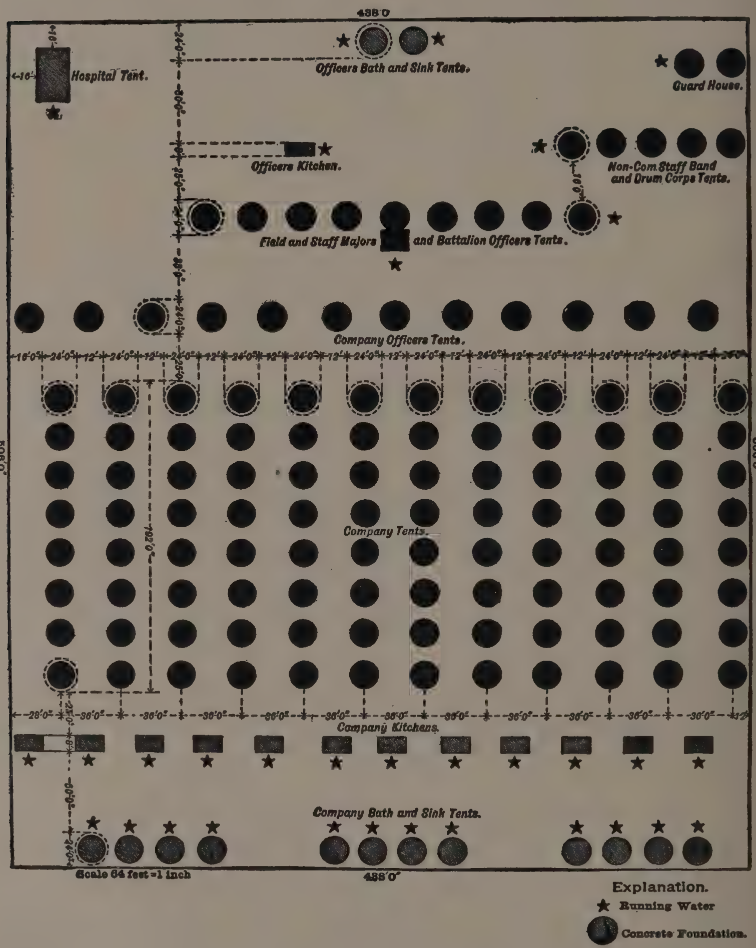
The general plan of a camp is shown in Fig. 98, taken from the Infantry Drill Regulation, and amended in the matter of distances and intervals by Dr. P. C. Harris, U. S. A.,[1] since no distances and intervals are given in the regulation, for they must vary according to the nature of the ground and the strength of the command. The plan is made "on a basis of 3 men to a common tent or 10 to a conical wall tent; the maximum allowance of tentage is 6 men to a common tent and 20 to a conical wall."

Sites.—One of the most important matters connected with military hygiene is the selection of a proper site for camps. Everything bearing on the health of those who are to occupy the camp should be considered important, and every effort should be made to insure, so far as it is possible, that there is no point of least resistance in the barriers against disease. If an unhealthy site is chosen, no amount of care can

[1] Camps of Instruction, Reprint, Buffalo, Dec. 14, 1898.

ward off, though it may check the extent of, evil consequences. In active warfare, choice of sites is not always a wide one, and convenience and necessity play a greater part than sanitary consideration. When practicable, they should be placed on high, well-drained ground.

FIG. 98.



Plan of camp (reduced so that scale of 64 feet to the inch no longer applies).

Proximity to water is always necessary, and this may involve exposure to malarial infection; but, other things being equal, the driest site should be selected. Where the choice is restricted, advantage should be taken, in cold weather, of any available protection from winds, and, in hot climates, from the burning sun. The general slope of the ground should be considered, so that surface drainage may be best provided for.

The soil should be dry and porous; clay and other soils of low permeability to air and moisture, but with high retentive power for the latter, should, if possible, be avoided. If the ground-water level is high, it should be lowered by tile draining or ditching, in case the camp is to be one of permanence. A clay soil or a soil underlaid at a short distance by a clay soil is regarded commonly as the worst possible site for a camp, since it is retentive of water and is cold, and causes the atmosphere immediately above to be damp. Old river bottoms, deep alluvium, and marshy ground should be avoided. Grass land may commonly be accepted as good camping ground, but ground covered with rank vegetation, as in the tropics, is not acceptable, because such is generally rich in decaying organic matter, and the presence of rank vegetation is in itself evidence either of a very humid atmosphere or of an undesirable degree of soil moisture. Lands subject to periodical flooding, especially by salt water, should be avoided as unhealthy.

Above all, it should be a rule to avoid old camp grounds, for these usually are left in a filthy condition by the previous occupants, and the soil is always contaminated extensively and, perhaps, infected. If an old camp site is particularly desirable on account of the accessibility of wood, water, and grass (the three essentials demanded by the line officer), a position to windward and as near as is consistent with hygienic considerations may be selected.

Dryness of the site and vicinity is of prime importance in its bearing on the health of troops, but too great dryness with much dust is hurtful to the eyes. A position on the side of a hill is warmer than one at the top and drier than one at the bottom, and is favorably situated as regards that most essential provision in camp sanitation, drainage.

Barracks.—Barracks are permanent structures for the lodgment of soldiers, and are built commonly of one or two stories, but not more. Each building of a group should be completely independent of the others and placed with reference to prevailing winds and exposure to the sun. It is essential that the site be dry; the foundation walls solidly laid; the walls, of whatever material constructed, dry and protected against capillary moisture; the floors, of hard wood, tightly laid; and the ventilation efficient. Barrack rooms, which are the soldiers' living rooms as well as sleeping quarters, are generally made long and narrow, and each occupant has floor space and air space according to the regulations obtaining in the country which he serves. In this country, 600 cubic feet of air space per man are reckoned adequate, and this, in a room 12 feet from floor to ceiling, gives a floor space of 50 square feet. Cavalry and artillerymen are given somewhat more, on account of the odors which cling to them from contact with horses. A less amount is allowed when troops are quartered in ordinary dwellings. At Southern posts, 800 cubic feet of air space and 70 square feet of floor space are allowed. In England, the allowances are the same as with us for infantrymen in the North; in India, they are from 1500 cubic feet and 75 square feet to double those limits. In France,

the cubic space allowed is 420 cubic feet for infantry and 500 for cavalry. In Germany, it is 500 cubic feet.

The wash-rooms, urinals, and latrines should be placed with due regard to convenience and to general hygienic considerations.

Ventilation should be planned with a view to the greatest possible reduction of the natural impurities due to occupancy, but with the present cubic space allowance, whatever the system employed, ideal results cannot be attained. Barrack life is necessarily one of overcrowding, but the conditions which now obtain are far superior to those which formerly prevailed. The evils of overcrowding of soldiers were first brought to light by an investigation of the health of British soldiers in 1858. It was shown that, whereas the mortality rate of the population of England and Wales of the same age as the army was 9.2 for town and country and 7.7 for country alone, and 12.4 for the most unhealthy town (Manchester), that of the different arms of the service ranged from 11 for the household cavalry to 20.4 for the footguards. According to age periods, the mortality was distributed as follows:

Ages 20 to 25.	Civilians	8.4
	Soldiers	17.0
Ages 25 to 30.	Civilians	9.2
	Soldiers	18.3
Ages 30 to 35.	Civilians	10.2
	Soldiers	18.4
Ages 35 to 40.	Civilians	11.6
	Soldiers	19.3

Since the soldiers were picked men, all applicants with any evidence of weakness or tendency to disease being rejected, these data indicated a serious condition of affairs. Comparison was made with the rates obtaining among the class of agricultural laborers, their work, like that of the soldiers, being mainly out of doors. It would be expected that the latter, being well clothed, housed, and fed, and given free medical care, would present the better showing, but such proved not to be the case, for the mortality of the laborer being expressed as 1, that of the household cavalry was 1.8, dragoons 2.2, infantry of the line 2.9, and footguards 3.3. Comparison with men in other occupations showed that the soldiers presented the most unfavorable statistics.

Inquiry as to the cause revealed that, whereas among civilians at the soldiers' ages the deaths from diseases of the lungs were 6.3 per 1000, they were 7.3, 10.2, and 13.8 respectively for the cavalry, infantry of the line, and guards; and, furthermore, that of the entire number of deaths from all causes in the army, the proportion due to lung diseases amounted to 53.9, 57.3, and 67.7 per cent. respectively in the arms above mentioned. Finally, by exclusion, the cause of this great mortality was attributed to overcrowding and lack of ventilation. Comparison of the mortality of the army at home with that of the troops quartered before Sebastopol in 1856 was much in favor of the latter. The rates, reckoned per annum, were as follows: Before Sebastopol, including death by violence and accident, 12.5; at home, 17.9 (infantry), and 20.4 (guards).

Increase in space allowance was soon followed by a marked decrease in phthisis mortality.

Tents.—In the United States Army, four kinds of tents are used: 1. The conical, or modified Sibley, tent. This is 16 feet 5 inches in diameter at the base; wall, 3 feet high; apex, 10 feet from the floor; the area of the floor equals 212 square feet; the air space, 1450 cubic feet; allowance, 20 infantry or 17 cavalry. The original Sibley tent had a diameter of 18 feet at the base and was 13 feet high. The apex was cut off, thus giving place to a circular aperture which, being left open in fair weather, promoted ventilation. In foul weather, it was covered. The allowance was the same. 2. Common tent, "I" or modified "A." Wall, 2 feet high; base, 8 feet 4 inches by 6 feet 10 inches; ridge, 6 feet 10 inches from the ground; floor space, 57 square feet; air space, 250 cubic feet; allowance, 4 mounted or 6 infantry. 3. Wall tent. Wall, 3 feet 9 inches; floor, 9 square feet; ridge, 8 feet 6 inches above the ground; floor space, 81 square feet; air space, 500 cubic feet; covered by fly or false roof. 4. Shelter tent. These are issued to troops in the field, and are not regarded as tent allowance, but are provided in order that men and officers in bivouac while on active campaign or on the march with deficient means of transportation may be sheltered. One forms a shelter for 2 men, each of whom carries his half, which weighs about $2\frac{1}{2}$ pounds. The pieces are joined together by buttons and put over a ridge pole, which is supported by uprights about 4 feet high. The corners are fastened to pegs driven into the ground, and the uprights are steadied by guy lines. Hospital tents are wall tents of a larger size; they may be closed or open at the ends, and several may be joined together so as to make a continuous whole. They are 14×15 with a $4\frac{1}{2}$-foot wall; ridge, 12 feet from the ground.

The English army uses the circular, or bell, tent. Diameter at base, 12 feet 6 inches; walls, 1 foot; apex, 10 feet; floor space, 123 square feet; air space, 492 cubic feet; allowance, 12 to 16 men, and in war 18 to 20. Formerly, the ventilation was practically *nil*, but now it has been somewhat improved. The French army uses a similar tent, ventilated at the top. The air space is 1059 cubic feet; allowance, 16 men. The Germans use a conical tent like the English bell tent. Diameter, under 15 feet; apex, 12 feet from the ground; floor space, 180 square feet; air space, 1050 cubic feet; allowance, 15 men. They use also small bivouac tents designed to shelter 2 or more men. The different parts are distributed among and carried by the men who are to use them.

It will be observed that, of the four armies mentioned, ours is the most liberal in point of air space, the minimum allowance in the larger tents being $72\frac{1}{2}$ cubic feet, against a maximum of 41 in the English service, 66 in the French, and 70 in the German service.

The material of which tents are made is cotton duck, which has proved to be much better for shedding water than linen. Comparatively little ventilation occurs through this material under the best

of circumstances, and none at all when it is wet by rain, for then it is impervious to air. Ventilation of tents is always defective, and commonly the atmosphere becomes exceedingly foul. Since there is so little ventilation, it is necessary that the sides should be kept raised during the day, in order that thorough airing, and, if possible, sunning, may occur; and at night, when practicable, the sides to leeward should be open, and the others, too, if advisable.

Dr. Edward L. Munson, U. S. A.,[1] has suggested improvements in the regular tentage, and especially in the hospital tents, for service in our tropical possessions, since the several forms in use, although well adapted to our climatic conditions, are intensely hot and close in the high temperatures and humid atmosphere that there obtain. He proposes enlarging the tent fly of the hospital tent 2 feet in length and 4 in width, and that it be raised upon a light false ridge, 4 feet longer than the true ridge and projecting 2 feet to the front and rear. Further, he proposes that the canvas forming the top of the tent be cut out for a space 2 feet wide on each side of the ridge and running the entire length of the tent, except 1 foot, front and rear, the canvas thus removed being replaced by heavy rope netting with a 2-inch mesh. In order better to reflect the heat rays, the fly should be made of white canvas, the tent itself being of dark canvas, with a view to subduing the light in the interior. An experimental tent, made under orders of the Surgeon-General, was pitched within a few feet of a regular hospital tent and a regular conical wall tent, for purposes of comparison. Thermometric observations showed an average difference of 7 degrees in favor of the improved tent, which was never less than 4.5 degrees cooler, twice was 8.5 degrees, and once 10.5 degrees cooler than the regular hospital tent. Compared with the conical wall tent, the temperature ranged 9.5 to 18.5 degrees lower in the improved tent, which difference "means in the tropics all the difference between comfort and distress for the well and such relief from great and depressing heat as would do much to bring about recovery in the sick." The experimental tent demonstrates that no tent should be issued for use in the tropics without the protection afforded by a fly. The U. S. A. Board of Equipment promptly adopted the improved hospital tent.

Dr. Myles Standish, M. V. M.,[2] first called attention to the intense white glare to which the occupant of the hospital tent is subjected from the covering above his head, and which must be a source of actual injury to eyes already in a pathological condition. Reasoning from general laws, he recommends a pale blue or an olive green as the safest color.

In India, the British use a tent with a double fly, having an air space of 2373 cubic feet and accommodating 16 healthy or 8 sick men,

[1] Tentage for Tropical Service, Boston Medical and Surgical Journal, Nov. 16, 1899, p. 487.

[2] Color the Canvas of Hospital Tents. Reprint, Transactions of the Association of Military Surgeons of the United States, 1896.

which gives a far greater allowance of space than in the service elsewhere. For field service, tents of 686 cubic feet capacity, accommodating 16 British or 20 native soldiers, and smaller ones of 392 cubic feet capacity, accommodating 8 British or 10 native soldiers, are in use.

Tents are arranged best in short single lines, the individual tents being distant from each other at least once and a half the tent's diameter; the intervals are not fixed by regulation. If possible, the tent should face the east, so that when the day is advanced, the southern wall may be lifted so as to admit the sun's rays to the whole of the interior. Each tent should be ditched as soon as it is placed in position.

The tent ditch should be 6 inches wide and 4 deep, and should connect with the company ditches, and these in turn with each other, forming a complete system of surface drainage. All surface drainage from higher ground should be prevented by being intercepted and turned aside.

The floor of the tent should never be lowered by excavating, for men should sleep above the level of the ground, and never below it. If the soil is not quite clean and firm, it should be dug out to the depth of about a foot and replaced by clean gravel or sand, if such is obtainable, and then covered with boards. Elevated platforms are eminently desirable, and tents not so provided should be moved every week to the open spaces between, so that the sun may exert its purifying influence and, together with fresh air, may put the vacated sites again in a condition for occupancy. The floors of the tents should, when possible, be covered with loose boards, if these are obtainable; and occasionally the surface of the soil should be scraped and replaced with clean gravel or sand. In malarial and yellow fever districts, nettings to exclude mosquitoes, especially at night, and individual netting on light frame-work for the protection of the head, the other parts of the body being protected by clothing, will be found to have great influence in checking infection.

Huts.—During cold weather, wooden huts are much better adapted for occupation than tents, and have come into extensive use in the German, French, and English armies, both in war and in time of peace. The use of log cabins is advocated by Colonel Charles Smart, M.D., U. S. A., to house 4 men apiece. The inside dimensions given are 13×7 feet; walls, 6 feet; ridge, 10 feet from the floor; the door to open in the middle of one side; the chimney opposite the door outside the wall; the roof consists of canvas 14×12 feet, with a larger fly. This is regarded as the best size and allowance, but the present tactics require squads of 8, for whom, according to Woodhull, "there should be two huts 8×11 feet end to end, 6 feet apart, with one continuous roof and door in the adjacent ends, but not midway. The chimney should be in the middle of one long end. Two platforms each $6\frac{1}{2} \times 4\frac{1}{2}$ feet, one lengthwise and one across the end, would accommodate 2 men, sleeping with their heads adjacent. The covered

porch between the huts would be 6 × 9 feet in the clear, the sleeping platform be open beneath, and under no pretence should two-storied bunks be allowed." On damp sites, the walls should be raised a foot from the surface; but on dry soil, they may be built directly on the ground level, the soil well pounded down, covered with sand and gravel, and concreted.

The floor of the huts raised from the ground is made best of split or dressed logs. The canvas roof and fly are attached in such a way that they may readily be removed when it is desired to admit the sun to the interior. Portable huts may be furnished, having frames of wood or iron. The German huts are made with wooden or iron frames covered with felt and lined with canvas. They are easily ventilated and warmed. The French huts are made circular in shape; the walls are of boards with glass windows. They are easily ventilated and heated. The huts should be at least 10 feet apart at the ends, and the interspaces should be carefully protected from pollution.

Water Supply.—It goes without saying, that one of the first considerations in the establishment of a permanent camp is an adequate supply of potable water, which subject is presented elsewhere. It is customary to allow at least 5 gallons per capita per diem for all purposes, and as much more as is practicable. Water-closets and baths require, naturally, a very generous allowance. Hospitals require much more per capita than barracks. For horses, from 5 to 10 gallons per diem are required. In general, it may be said that the more generous the supply, the greater the general cleanliness and efficiency.

In temporary camps, the supply, both as to quality and quantity, is determined by natural conditions, and must be taken as it is found. If purification of that intended for drinking appears to be necessary, the methods mentioned in the consideration of the subject of water supplies may be adopted according to availability. The simplest are boiling and the application of alum, with subsequent filtration, if possible, through sand held in suitable receptacles such as half barrels with perforations through their bottoms. The so-called "mechanical filters," so much used in the purification of public water supplies, are more efficient and convenient. Experience has shown that, no matter how urgent the necessity for care in the avoidance of pollution of water, it is always difficult to prevent some of the men from recklessness in drinking. The operation of purification should be in the immediate charge of a non-commissioned officer, properly instructed and with a suitable detail.

Sewerage.—The introduction of an abundant water supply in a camp is, of course, followed by more or less lavish use of water for all general purposes, and this necessitates a system of sewerage for carrying off liquid waste and human excreta. Camp sewers should be constructed in a proper manner of bricks or drain-pipe, and never of wood. The method of final disposal of the sewage at the outfall will depend upon individual circumstances. All permanent camps should be properly sewered.

In case of outbreaks of typhoid fever, cholera, or other diseases of the same general class, the excreta should be disinfected before being otherwise disposed of. In army practice, chloride of lime 4 per cent. and carbolic acid 5 per cent. are commonly used, with weaker solution of carbolic acid and corrosive sublimate 1 : 1000 for washing floors and articles of furniture or for soaking soiled clothes. Milk of lime is highly to be recommended for excreta, as is also formaldehyde solution, if it can be obtained. The Manual for the Medical Department says on this point: "Sulphate of iron and other cheap antiseptics and deodorants may be used when necessary. But the necessity for their use is a reproach upon the sanitary police of a post, and should only be required under exceptional circumstances, The alvine discharges of healthy persons do not require disinfection. and when properly disposed of, do not require treatment with any chemical agent whatever. If water-closets or earth-closets are offensive, this is due to faulty construction, to insufficient supply of water or dry earth, or to neglect of ordinary cleanliness. The attempt to remedy such defects by the systematic use of antiseptics is expensive and unsatisfactory in its results. The same is true of foul drains, bad smelling urinals, accumulations of garbage, etc. The proper remedy for such conditions is cleanliness and strict sanitary police."

When there is reason to believe that infectious diseases are present in camps, the latrines and cesspools should be disinfected with milk of lime to the extent of one-twentieth of their contents, to which should be added every day an amount equal to at least a tenth of the daily addition of excrement. Hospital sewage is dangerous enough to warrant treatment on the spot with disinfectants.

In the absence of a regular system of sewerage, Sternberg recommended cylindrical galvanized iron vessels 18 inches in depth and diameter, with a trough around the upper end 3 inches deep, filled with disinfectant. Into this, the cover fits, and thus serves as a valve and prevents the escape of foul odors and the entrance of flies. A second cover with a hole serves as a seat. The receptacle is to be partly filled with carbolic solution or the contents are to be treated with caustic lime, or ashes, or dry earth. These vessels should be removed at regular times, and clean ones should be substituted while they are removed, emptied, and cleaned.

Sinks and Latrines.—A sink, in military parlance, is a cesspool or privy vault in a temporary camp; usually, a trench from twelve to fifteen feet in length, about two feet in width and eight in depth, with the earth, which has been thrown up, piled along one side. The requisite number should be dug before a camp is occupied or as quickly thereafter as possible. They should be placed to leeward, or in such position that the prevailing winds shall not convey the odor therefrom over the company areas, and they should never be placed near existing wells. They should not be placed any farther away from the men's quarters than is absolutely necessary. For convenience of use, a strong pole is laid horizontally on upright forks at the proper height and on

the side opposite the excavated earth. The latter, kept as dry as possible, is thrown back each day over the deposited excreta, often with caustic lime, chlorinated lime, or ashes.

Behring[1] recommends, in case of necessity, from 5 to 7.5 liters of milk of lime for each 250 men; Pfuhl[2] advises 400 cc. per man. The addition of chlorinated lime possesses a double advantage, since it not only acts as a disinfectant, but also serves to drive way flies, which otherwise collect and may become active agents in the spread of infectious disease.

Small sinks for each company are regarded as much better on several accounts than one or more large ones for each regiment. They afford greater privacy when enclosed with brushwood, and are generally better looked after, since the responsibility for their care is more definitely fixed. When filled to within two feet of the surface, the remaining earth should be thrown in and rounded over, the site marked, and, at the same time, new trenches prepared. On breaking camp, all sinks, however little used, should be filled up and marked.

When the probable stay is to be more than of a few days' duration, the horizontal poles are commonly replaced by box seats, open at the back. In winter, the trenches should be completely covered by box seats with covers; hinging of the top or rear side will be necessary for the proper throwing in of the excavated earth.

The word *latrine* is commonly used as synonymous with *sink*. It is properly defined as "a privy or water-closet, especially in trough form accommodating several at the same time."[3] A further description of a latrine is elsewhere given (see page 612). Latrines are more commonly installed in barracks or permanent camps. They require frequent flushing, if connected with a system of sewerage, and frequent emptying and cleansing, if not so connected. The seats and floors should be kept thoroughly clean by periodical washing; twice daily is strongly recommended.

Urinals apart from sinks and latrines are installed in both permanent and temporary camps, and in both it is essential that they be of easy access, and their use compelled on account of the nuisance arising from indiscriminate voiding of urine on the ground and of the possibility of the dissemination of typhoid fever by the urine of ambulatory cases of that disease and of convalescents therefrom. In inclement weather and at night, all parts of a camp, and especially the company areas, are liable to urinary contamination, which should be prevented as far as possible by stringent rules and constant vigilance.

Inspections.—Under the Army Regulations, an annual inspection of the buildings at every post is made by the commanding officer and quartermaster on the first day of March, and immediately afterward a report is submitted giving a description and showing the condition and capacity of each building, and the character and extent of any additions, alterations, and repairs. Sanitary inspections are more fre-

[1] Zeitschrift für Hygiene, IX., p. 395.
[2] Ibidem, IV., p. 97.
[3] Standard Dictionary.

quent and more searching in character. The surgeon is required to examine, at least once a month, and to note, in the medical history of the post, the sanitary condition of all public buildings, the drainage, sewerage, amount and quality of water supply, clothing and the habits of the men, and character and cooking of the food, and immediately after such examination to report thereon in writing to the commanding officer, with such recommendations as he may deem proper. Superficial inspection is not enough, for everything may look clean externally and yet the general condition may be bad.

The condition of the air is of much more importance during the sleeping hours than during the day; therefore, ventilation should be investigated at night. Walls and floors should be carefully examined, especially if they are made of porous material. Walls found to be contaminated with organic filth should be scraped and then thoroughly whitewashed. The floors, whether of barracks, tents, or huts, should be scrupulously clean and dry; the bedding should be free from dampness; the spare clothing and the men themselves and their clothing in use should be clean. The site and immediate surroundings of every permanent or temporary structure should be examined with particular reference to the drainage and general condition of the soil.

Sanitary Police.—Exceedingly strict sanitary policing is necessary to keep a camp in a healthy condition. The responsibility for condition rests with the commanding officer, but is shared in by the company officers, who must look after their quarters and men. Under the title of "officer of the day," company commanders serve in turn, each for a day, in charge of general sanitation, and each is responsible to his commanding officer for the order and cleanliness of the camp on the day of his service.

It has been demonstrated repeatedly that untrained or inexperienced soldiers cannot be depended upon for thorough cleaning or keeping things clean, for they do not know how to take care of themselves, because at home they are looked after by others; and unless sanitary police be very strict, a clean and everyway good natural site may quickly be contaminated and made unhealthy. Until discipline is well established, the enforcement of proper sanitary regulations is extremely difficult, for while they may be most carefully formulated, the necessary orders are difficult of enforcement. Even with the utmost care and vigilance, contamination of the site is only a question of time, but the more efficient the system, the longer is that time deferred. A camp in which no attention is paid to cleanliness of the company streets and to habits of personal cleanliness is sure to be an unhealthy one, and men who will permit such conditions to obtain are commonly bad soldiers in every sense of the word, with no *esprit de corps*, slovenly in all their habits, conspicuously attentive to sick call, and with no respect for themselves or their superiors.

In such a camp, the development of epidemics of infectious diseases, particularly typhoid fever, is only a question of time, since it needs only the introduction of the specific germ and favorable opportunities

for its dissemination. Since this disease is endemic in all parts of the country, it is not strange that among large numbers of men brought in from different quarters there should be one or more carriers of the infection. In any camp of whatever degree of efficiency in sanitary police, unless such cases are recognized at once and their excreta completely disinfected or otherwise disposed of, so that no danger shall be possible therefrom, the site is likely to become polluted and the bacilli to be distributed through the usual agencies.

One of the first essentials of maintaining cleanliness in camp is good surface drainage. If the soil is damp, the site soon becomes an expanse of mud, owing to the constant impress of hundreds of feet. Mud assists in the conservation of refuse and filth which it envelops and masks, and hence arises the necessity for efficient and thorough ditching, and for filling up depressions likely to retain surface water. The usual pathways and sidewalks should be made as dry as possible by the application of gravel, and by such other methods as are applicable to each individual case.

All refuse of whatsoever kind should be prevented from accumulating within the lines; everything should be promptly removed and disposed of, if possible, by burning. Kitchen refuse should be deposited in covered receptacles, which should be carried away twice daily. On no account should it be left exposed on the ground or elsewhere, since not only does it speedily develop the well-known nauseous odor of swill, and thus become a nuisance, but it is an attraction for flies, which, by their investigation of all sorts of filth, including the fæcal discharges in the sinks, and then of the soldiers' food both in the kitchen and at mess, have again and again proved themselves to be largely responsible for the spread of epidemic diseases, as will be explained more in detail on a later page.

The final disposition of kitchen refuse is often a problem fraught with serious difficulties. When possible, it should be burned in one of the numerous forms of incinerators devised for the purpose; but on no account should it be spread out in the vicinity of the apparatus to dry. If it be advisable to bury any part of it, at whatever distance below the surface it is deposited, it should be well covered with clean earth. The deeper it is buried, the longer will it resist complete decomposition.

Stable manure should be removed every day and deposited at a sufficient distance and in such a location as to insure that it shall not be a nuisance or a source of danger to the water supply. Incombustible harmless refuse should be removed out of sight, and not be allowed to accumulate, for anything promoting untidiness of appearance invites additional untidiness by its example.

Considering the many details of camp police and the necessity for coöperation on the part of every man, it is not strange that, in our war with Spain, the hasty gathering together of large bodies of undisciplined troops from all parts of the country into large improvised camps, largely under the control of inexperienced officers both of the

line and medical service, was followed very quickly by the outbreak of epidemic diseases, which carried off large numbers of men who, to a certain degree, were victims of their own carelessness. It is related, for example, that a certain regiment of volunteers, encamping nearly side by side with one of regulars, was invaded to an extraordinary degree by typhoid fever, while the regulars were practically free from disease. One of the medical officers informed the author that most of these men were so dirty, lazy, ignorant, intemperate, and immoral, that nothing short of an extensive epidemic among them could have been expected, and was expected from the start. They saw some active service, and were conspicuous for general inefficiency and lack of discipline. Their ranks were reduced very largely by disease, and the casualties were practically nothing. The survivors returned to civil life and were welcomed as heroes; those who perished in consequence of their own and their comrades' revolting habits of life are enrolled with those who sacrificed their lives in defence of their country's honor.

The necessity of constant supervision and of enforcement of discipline has been well set forth by John S. Wise,[1] who says: "To appreciate fully the truth that men are but children of a larger growth, one must have commanded soldiers. Without constant guidance and government and punishment, they become careless about clothes, food, ammunition, cleanliness, and even personal safety. They will at once eat or throw away the rations furnished for several days, never considering the morrow. They will cast aside or give away their clothing because today is warm, never calculating that tomorrow they may be suffering for the lack of it. They will open their cartridge boxes and dump their cartridges on the roadside to lighten their load, although a few hours later their lives may depend upon having a full supply. When they draw their pay, their first object is to find some way to get rid of it as quickly as possible. An officer, to be really efficient, must add to the qualities of courage and firmness, those of nurse, monitor, and purveyor for grown-up children, in whom the bumps of improvidence and destructiveness are abnormally developed."

A striking and interesting object-lesson in camp sanitation is given by Colonel Charles R. Greenleaf, M. D., Medical Inspector, U. S. A.[2] Two camps located very near together, nearly equal in the number of men contained (about 12,000), and with the same conditions of climate, soil, water supply, and food, showed very different records of morbidity and mortality. In one, "the men were scourged with sickness and death, and large numbers of them were permanently invalided; local epidemics became general, and soon the entire camp was so thoroughly infected that it was of necessity abandoned." In the other, "but little sickness (the percentage never exceeding five and a half of the aggregate strength), few deaths, and a few cases permanently invalided;

[1] The End of an Era, Boston, 1900, p. 347.
[2] An Object Lesson in Military Sanitation, Boston Medical and Surgical Journal, Nov. 16, 1899, p. 485.

local epidemics of contagious disease, due to importation," were quickly controlled, and never extended beyond the respective commands which brought them, nor did a single case of infectious disease originate in the camp.

The difference in the health conditions of the two camps was due to the fact that in one, "the advice of sanitarians was seldom asked, and when asked was not followed, and nearly every law of health was either ignored or violated," while in the other, "the advice of sanitarians was freely sought, accepted, and carried out, no pains being spared to secure, as far as possible, compliance with the laws of health." The benefits of sanitation were recognized by both officers and men, and the advice of its teachers was carried out by all to the fullest extent.

The following sanitary regulations, published for the governing of certain model camps established in the Presidio Reservation, one for five regiments of volunteers returning from the Philippine Islands, one for four regiments of out-going volunteers, or about 5200 men, and one for about 2000 recruits for the regular regiments already in the Philippines, are communicated by Dr. Greenleaf. ("In planning these camps the primary objects were to remove the kitchens as far as possible from the latrines, to provide a safe method for the disposal of excreta, garbage, etc., to secure means for the personal cleanliness of the men, to heat their quarters, and to supply them with an abundance of good food and water.")

"The commanding officer of the troops occupying the camps will detail from his command two sanitary inspectors; one from the line, preferably a major of the regiment, and the other a regimental medical officer, whose daily duty it shall be to jointly inspect the regiment, inquiring into the general police of the company quarters and streets, the kitchens, the food, its preparation, quality and method of serving, the latrines, urinals and sewers, and making to the regimental commander a brief report of any unsanitary conditions they may discover, this report to be forwarded the same day to the medical inspector of the army at department headquarters.

"One medical officer and one hospital steward from each regiment will be required to be present for duty with the regiment at all times of the day and night.

"A daily sick call will be held, and slight cases of illness treated in quarters or in the regimental hospitals provided for that purpose, but all men who are likely to remain sick more than three days will be promptly sent to the General Hospital at the Presidio of San Francisco.

"If any case of infectious disease occurs, the fact will be promptly reported to the camp surgeon, who is authorized to make proper disposition for its isolation and care.

"An ambulance fully equipped with a team will be assigned to the camp by the commanding officer of the Presidio. This ambulance will report daily to the camp surgeon at sick call, remaining in the camp

during the day, subject to his orders. Under no circumstances will this ambulance be used for any other purpose than the transportation of the sick, or medical supplies. The commanding officer of the Presidio will also cause another ambulance to be sent to the camp for service at night time. This ambulance will remain on duty from retreat to reveille for night emergency service. When the night ambulance reports for duty, the day ambulance will be relieved and returned to the post."

"Company commanders will caution their men against exposure to the fogs and high winds that prevail here, especially in the early morning and evening, at which time overcoats will be worn. Riding on the 'dummy' of the street cars, especially at night, is particularly hazardous to men recently returned from service in the tropics. Guard duty and other military functions required at these hours will be held in overcoats, and at breakfast and supper the stoves in the dining-rooms will be provided with fires. The sale, by civilians, of food or drink within the limits of the camp will be forbidden.

"At retreat, urine tubs, two to each company, will be placed in each company street, and men desiring to urinate at any time during the night will be required to use them. The tubs will be removed from the company street at reveille to a place convenient for the scavengers, who will remove, clean and place lime in them for use the next night.

"The quartermaster's department will be required to provide an ample force of scavengers to clean the latrines and urinal troughs at least once daily, and to refill the troughs with milk of lime; they will also remove all kitchen garbage, and either cremate it or dispose of it in such place as the quartermaster shall direct. Particular care will be enjoined on company cooks to keep grease traps clean, and to deposit all solid garbage in cans prepared for that purpose in time for its removal by the scavengers.

"The quartermaster's department will furnish to each regiment an ample supply of necessary policing implements, to enable the men to thoroughly and effectively police the camp daily."

These regulations, Dr. Greenleaf reports, were promptly carried out by officers and men, and, in spite of the fact that nearly every body of men brought some form of infectious disease, including typhoid fever, tropical dysentery, diphtheria, smallpox, measles, and mumps, not a single case of any infectious disease originated in the camps, all of the imported cases being promptly segregated from the command, all infected material disinfected or destroyed, and all men who had been exposed isolated and quarantined.

In all these camps, the latrines and bath-houses were placed on the flanks and rear; the kitchens and mess halls, in the central lines. In the rear of each mess hall, a zinc-lined wash trough, supplied with a dozen bib cocks, was placed to be used as a lavatory; near the door of each kitchen was a grease trap connected with the sewer, and galvanized cans for garbage and ashes were placed on the porch. Large

caldrons for heating water for laundry and other purposes were set up in convenient places. Two galvanized wash-tubs were furnished to each company, and "night soil tubs were placed in every company street at 'tattoo' for the use of the men during the night, a sentinel being posted in the street to see that the orders regarding their use were carried out." The construction of latrines and disposal of excreta were carried out according to the recommendations of a board of medical officers, consisting of Major Reed, U. S. A., and Majors Vaughan and Shakespeare, U. S. V., as follows:

"A trough made of No. 22 galvanized iron, fourteen feet long, twenty-two inches wide at the top, parabolic in cross section, and with a maximum depth of eighteen inches, if set in a light wooden framework, which serves as a protective crate in transportation, gives support to the trough while in position, and serves for the attachment of a lid in two sections, furnished with seven seat holes. These holes are shaped so as to render soiling of the seat difficult, and a slanting board one foot wide, permanently fixed at a proper angle above the seat, prevents the men from getting up on it with their feet. When in position, one end of the trough is raised four inches higher than the other. The trough is placed in an ordinary frame privy house. At the upper end of the trough there is placed a galvanized iron gutter of proper height and inclination leading into the trough to serve as a urinal.

"The rear side of the gutter or that attached to the wall of the building is higher than the front side, to prevent soiling the building. The trough is prepared for the reception of fæcal matter by filling it with water until a certain level, indicated by a line on the inside of the trough, is reached. A measure for the purpose, and holding one-sixth of a barrel, is now filled with quicklime and emptied into the water; some dry lime should also be placed in the urinal. The lime in the trough is thoroughly stirred with a wooden paddle. This stirring is repeated three times every day. The wooden paddle when not in use stands in a pail filled with milk of lime. Toilet paper is provided for the men's use in the latrines, because large pieces of newspaper will float on the water holding masses of fæcal matter above the surface, thus exposing it to the flies and other insects.

"Once a day the contents of these troughs are pumped out into an odorless excavator, carted away and properly disposed of. The milk of lime destroys the typhoid bacillus, and the contents of the trough, if properly cared for, will be quite innocuous. Not only is the milk of lime and fæcal matter innocuous, but its value as a fertilizer is considerable."

It may be stated, however, that these excellent results in sanitary police were not brought about without outside assistance, for it was found advisable to employ a corps of civilian scavengers consisting of 2 overseers, 22 night scavengers, 54 day scavengers, and 17 teamsters, with 5 odorless excavating carts, 6 sanitary cars, and 12 dust carts. By means of this outside force, the camp was kept thoroughly clean, and the excreta were promptly removed and disposed of. The latrine

troughs were emptied twice in twenty-four hours, and garbage and all manner of waste material were removed twice daily. The tent floors, kitchens, mess halls, and company streets were swept daily by the soldiers themselves, and one man from each company did duty each day in the company latrine to keep it clean and stir the lime solution frequently.

The Diseases of the Soldier.

While there are no diseases peculiar to the soldier, there are many to which the circumstances and conditions incident to camp life render him conspicuously susceptible. These are mainly of the preventable class, and may be largely checked by proper regard to the principles of camp sanitation, by avoidance of polluted water, improper cooking, overcrowding, and overwork, and, in some degree, by the inculcation of the principles of moral living.

It is difficult or impossible to determine how soldiers compare with civilians in the amount of sickness which they suffer, since we have no statistics of general morbidity, especially of corresponding age periods, of the civil population; and even were such available, it would be necessary to bear in mind that the soldier is often on the sick list with ailments which, in civil life, would neither deter him from attending to his daily work nor cause him to go to the added expense of medical advice. The soldier has absolutely free medical attendance and care, and of this he freely avails himself, excepting, with many, in case of venereal troubles.

Concerning the constitution of the medical corps, the hospital accommodations, and general administration, all of which are fixed by law and regulation, no description or discussion is necessary; and a brief consideration of the prevalence and predisposing causes of the chief diseases of armies is all that lies within the scope of this work.

It is a well-known fact that in both war and peace the greatest mortality among soldiers is from disease, and not from violence, the single exception which history records being afforded by the German army in the war of 1870 with France. In our war with Mexico, according to Woodhull, 935 of the regular force were killed or died of wounds, and 4714 died of disease in the field. In the Civil War, 99,183 whites and 3417 negroes were killed or died of wounds, and 171,806 whites and 29,963 negroes died of disease. In our war with Spain and troubles in the Philippines, during the year from May 1, 1898, to April 30, 1899, according to the report of the Surgeon-General, 968 men were killed or died of wounds, injuries, and accidents, and 5438 died of disease. Typhoid fever was responsible for more than half the deaths from disease; next in order came malaria, followed by pneumonia, yellow fever, and smallpox.

Tuberculosis.—In the large standing armies of the world, tuberculosis has long played a leading part, due largely, as has been pointed out, to overcrowding and deficient ventilation, and to the enlistment of men in whom the disease is latent before entrance and developed by

changes in habits of life, climate, etc. Yet, according to Colin,[1] Inspector-General of Hygiene in the French Army, many persons with latent tuberculosis not only withstand the hardships of military service well, but even become stronger and generally healthier. According to a statement by Surgeon-General Schjerning at the Tuberculosis Congress in Berlin (1899), a decided decrease in tuberculosis has been observed in the German army, while in other armies an increase from year to year in loss of men from this cause may be looked for as a certainty, especially when large increases in enlistment necessitate the inclusion of many not fit for service. Colin's statistics of losses to the French army are corroborative of Schjerning's statement, especially those for the year 1895, when a large increase of the army, necessitating a reduction in the quality demanded, was followed by a more marked increase in yearly loss. The figures follow:

Year.	Discharges per 1000 army strength.	Deaths per 1000 army strength.	Total loss per 1000 army strength.
1888	4.30	1.18	5.48
1889	4.94	1.05	5.99
1890	5.70	1.08	6.78
1891	6.10	1.33	7.43
1892	6.55	1.04	7.59
1893	6.33	0.94	7.27
1894	6.55	1.01	7.56
1895	8.34	1.14	9.48
1896	7.34	0.94	8.28

In the English service, phthisis is the chief cause of mortality and invaliding, the annual loss averaging somewhat below 5 per 1000 army strength. In the French service, the disease stands second to typhoid fever.

In armies, as in general life, tuberculosis finds the greater number of its victims among those who are most confined, and is more frequent in the garrisons of large towns than among troops in the less thickly settled parts. The most careful prophylaxis is demanded to prevent its spread, and the ideal measures would include the discharge of all persons capable of acting as foci of the disease.

Typhoid Fever.—Typhoid fever is very prominent as a scourge, especially in time of war, when large bodies of raw and undisciplined troops are brought together in camps of instruction. Among large bodies of men drawn from different parts of a country in which the disease is very generally distributed, it is almost inevitable that there will be some who will introduce the specific germ. The individual soldier, owing to age and the abrupt changes in the nature of his surroundings and general habits of life, is very susceptible to infections in general. Statistics demonstrate that the seasoned regular suffers much less from disease, in proportion to numbers, than the undisciplined volunteer and raw recruit. This is due to the fact that he

[1] Journal d'Hygiène, March 1, 1900.

has become accustomed to the mode of life, and, through training, has learned better how to take care of himself in all departments of personal hygiene. Great care is necessary to isolate cases as soon as recognized, and to treat excreta so that their final disposal shall not be a menace to the safety of others.

Of the highest importance is the prevention of access of flies to the discharges, for, as has been stated elsewhere, these pests have been responsible for the spread of this and other diseases by contaminating the food supply after visiting the sinks. Also of the highest importance is the avoidance of a polluted water supply; boiling of water concerning which nothing is known should always be done as a matter of routine precaution, and the attention of the men should be drawn to the danger which they incur in the indiscriminate drinking of water which has not been thus treated or shown by competent authority not to require it. In general, it may be stated that, without efficient sanitary police, typhoid fever among troops is always to be expected.

The origin and spread of typhoid fever in our army during the Spanish War (1898) were investigated by a board consisting of Dr. Walter Reed, U. S. A., and Drs. V. C. Vaughan and E. O. Shakespeare, U. S. V., who reported that more than 90 per cent. of the volunteer regiments developed the disease within eight weeks of going into camp. In certain regiments of regulars, the disease developed within three to five weeks. Among the whole body of troops there were no less than 20,000 cases between May and September. The causes included polluted water and dissemination of fæcal matter by flies. In some cases, camps were set up despite the protests of the medical officers against the unfitness of the sites selected.

Preventive inoculation against this disease, although in its infancy, has given sufficiently encouraging results to warrant trial on a large scale. The great majority of English troops sent to war in South Africa were so treated, and statistics concerning the efficacy of the treatment have demonstrated its value.

Dysentery.—In the South and in our new tropical possessions, dysentery is one of the most important camp diseases; in fact, it is said that, within the tropics, dysentery annually claims far more victims than Asiatic cholera. Once introduced, like typhoid fever, it is likely to become epidemic. Prophylactic measures adopted are the same.

Malaria.—The various forms of malarial diseases are always a curse to armies, especially those operating in hot climates. Though the death roll from malaria may not be great, sickness and consequent invaliding are commonly enormous in amount, and an army stricken with malaria is an army unfit for field operations. The infection weakens the natural power of resistance to other infections, and is said to predispose the victim especially to infection by typhoid fever, and to exert a particularly pernicious influence on those who have already acquired or subsequently acquire venereal diseases.

Since the confirmation of the discovery of the important part played by mosquitoes in the dissemination of the malarial poison, the necessity of the use of netting against these pests has been very clearly demonstrated. The preventive measures against malaria consist in the avoidance, if possible, of sites near which the conditions are favorable to the puddle-breeding mosquitoes, the avoidance of unnecessary going about during the hours when mosquitoes are most active, prevention of access of mosquitoes to the sleeping quarters, and the systematic use of prophylactic doses of quinine morning and night. Whiskey is not needed as an adjuvant, and is more likely to be an injury than an aid. Hot tea and coffee are more highly regarded.

Measles.—In all new levies of troops, measles is a serious impediment to efficiency, for, once introduced, the disease spreads rapidly through the camp, especially if the troops are largely from the country, where they have escaped the diseases of childhood which ravage the population of cities and large towns. The importance of the disease appears, according to recent evidence, to be likely to be underrated by commanding officers.

Diarrhœal Diseases in General.—Because of the lesser resistance to specific infections, which appears to accompany even mild conditions of diarrhœa, it is essential to take such measures and precautions as are possible to prevent them. Among the prominent causes may be mentioned the use of improperly cooked, indigestible food, and chilling of the body, particularly at night while sleeping on the ground, even although separated from immediate contact therewith by rubber blankets. The prevention of the first cause needs hardly to be pointed out; for the prevention of the second, the habitual use of light flannel garments or abdominal bands is recommended.

Sunstroke.—This consequence of extreme heat or over-exertion in high temperatures is very likely to be induced by imprudence in the matter of water supply, and by continuous work without periods for rest and recreation. According to Dr. Smart, U. S. A.,[1] "If the allowance of water is scanty, it must, nevertheless, be used at regular intervals, but economically, lest it give out. There is manifestly less danger of a fulminant stroke with a stinted but steady supply than with full allowance for a given time followed by a period of enforced abstinence. On the other hand, if the supply is liberal, it may be indulged in freely and with advantage when the skin is acting well." He relates that, during a service of four years in the hot climate of Arizona, with commands of varying size, making long marches, often on scant allowance of water, he saw sunstroke on but one occasion, and in this instance, the rule to use the canteen in the early part of the march with caution, as if no more could be had until arrival in camp, was not followed. It was the rule, when a supply presented itself on the line of march, to use it freely, and then, on proceeding, to use the refilled canteens with the same caution as before. A canteen of tea,

[1] Philadelphia Medical Journal, January 19, 1901, p. 158.

not necessarily strong, containing a little lemon juice, lime juice, or vinegar, is more desirable when obtainable than plain water.

Venereal Diseases.—These are responsible for a very large amount of sickness in all armies, and their prevention has been the subject of much consideration by military authorities everywhere; but the remedies against the prevailing high figures of morbidity, namely, scientific and practical control of prostitution, find always and everywhere active opposition on the part of the public.

CHAPTER X.

NAVAL AND MARINE HYGIENE.

The conditions of life at sea in relation to health are very different in many respects from those which obtain ashore. The seafaring man, wherever he goes, travels in his habitation, in which, necessarily, his share of cubic space is far less in amount than that which the principles of general hygiene stipulate as a permissible minimum for those ashore. His air-supply while at work on and above the deck is of the greatest known purity, and while below in his sleeping quarters it is likely to be at times unutterably foul, and under usual conditions, even with the best of care and appliances, is usually not in conformity with the generally accepted standard. His work exposes him to the hardships of the most inclement weather, to extremes of heat in the stokeholds of vessels propelled by steam, to long-sustained muscular effort at critical periods; and involves short hours for sleep, and these not in one consecutive whole, but divided by intervening periods of duty. His food supply for the entire period from port to port must be transported with him, must necessarily possess keeping qualities, and hence consists largely of preserved instead of fresh meats, and dried and canned vegetables instead of those fresh from the fields.

In the matter of kitchens, cooking appliances, and fuel, he is circumstanced more fortunately than the soldier, since wherever he goes they accompany him, and he is independent of the frequently troublesome question of transportation of supplies and appliances in time of need. Thus it was that, during the battle of Manila Bay, all hands could be piped to breakfast, whereas at the fierce onslaught by the land forces at San Juan, no such comfortable relief could be afforded.

His water-supply must be carried in proper storage or be obtained by distillation from the salt water in his path. But he has not to cope with the difficulties which beset the soldier in the matter of camp sanitation, for his sewer is the boundless ocean, and the question of disposal of garbage requires no thought.

NAVAL RECRUITS.

The United States Regulation forbids the enlistment as a landsman of any man over 25 years of age unless he has learned some mechanical trade, and in this instance he may not be enlisted, without special authority, if over 34 years of age. A landsman is one who never before has gone to sea, or, having been already at sea, does not possess the skill required of an ordinary seaman. An ordinary seaman must already have had two years' experience. An able seaman is one who

has had at least four years' experience and understands the navigation of ships. Apprentices are enlisted not under 16 years of age, and serve as such until 21, when their term expires.

A candidate for the service is required to undergo a thorough examination. If afflicted with stricture, internal piles, or any serious disease, or suffering from the results of any former disease or injury, or subject to fits, he is debarred from the service. Applicants for positions as skilled mechanics must demonstrate their knowledge of their craft, and show that they possess the necessary qualifications for following it.

THE NAVAL RATION.

The naval ration is always different from that of the soldier, for reasons already given. The ration of the United States Navy, as prescribed in 1902, consists of the following daily allowance of provisions to each person: "One pound and a quarter of salt or smoked meat, with 3 ounces of dried or 6 ounces of canned fruit and 12 ounces of rice or 8 ounces of canned vegetables, or 4 ounces of dessicated vegetables; together with 1 pound of biscuit, 2 ounces of butter, 4 ounces of sugar, 2 ounces of coffee or coca, or $\frac{1}{2}$ ounce of tea, and 1 ounce of condensed milk or evaporated cream, and a weekly allowance of $\frac{1}{2}$ pound of macaroni, 4 ounces of cheese, 4 ounces of tomatoes, $\frac{1}{2}$ pint of vinegar, $\frac{1}{2}$ pint of pickles, $\frac{1}{2}$ pint of molasses, 4 ounces of salt, $\frac{1}{4}$ ounce of pepper, and $\frac{1}{2}$ ounce of dry mustard. Five pounds of lard or a suitable substitute will be allowed for every hundred pounds of flour issued as bread and such quantities of yeast as may be necessary."

Preserved meats, in the meaning of the law, comprise canned beef, mutton, corned beef, bacon, ham, sausages, salted fish, and any other smoked or salted meats. Flour comprises wheat, rye, oatmeal, cornmeal, and hominy. Dried fruits include apples, peaches, prunes, raisins, dates, figs, and others susceptible of preservation by drying.

From the above, it will be noted that our naval ration is very elastic and generous, and, indeed, is said to be superior in amount and variety to that of any foreign navy, just as our army ration surpasses in these respects those of other armies.

In spite of the elasticity and abundance of the ration, considerable improvement and much greater satisfaction appear to be attained by the system of the consolidated mess, instituted originally, in 1889, by Lieutenant Delehanty, of the U. S. S. *Independence*. Not the least of its advantages is the improvement in the preparation and serving of the food. In the ordinary method of messing, the ship's company is divided into a number of messes of about twenty men, and each has its own cook and mess attendants. The preparation of the food for all is in charge of the chief cook and a number of assistants, and the serving out and the care of the mess gear are attended to by the mess attendants or berth-deck cooks. According to Lieutenant B. C. Decker,[1]

[1] The Consolidated Mess of the Crew of the U. S. S. Indiana, Proceedings of the U. S. Naval Institute, XXIII., 1897, p. 463.

of the U. S. S. *Indiana*, "the present system of messes with incompetent and often broken-down landsmen as cooks, . . . and with general waste and mismanagement, is a failure."

In the consolidated mess of the *Indiana*, as described by Decker, the crew of 380 men have a common interest, and are attended to by seven cooks, one of the first class, two of the second, and four of the third class, a commissary yeoman, and a storeroom keeper. Funds for provisioning the mess are derived from the commuted rations and the canteen. (Here may be stated that, in the discussion of the paper noted, the canteen system, as it existed in the Navy, was the subject of severe criticism by officers of the line. It is now abolished.)

The system saves much trouble, requires fewer cooks, and by making possible the purchase of a still wider variety of food materials, insures greater satisfaction throughout at a diminished cost.

The principal defects of all dietaries for seafaring men comprise monotony, deficiency in vegetable components, and excess of preserved meats. In order to guard against the results of an insufficient supply of antiscorbutic vegetables, the Revised Statutes require that all vessels of more than 75 tons bound across the Atlantic or Pacific or around Cape Horn or Cape of Good Hope, or engaged in whaling or sealing, shall carry a sufficient supply of lemon juice or lime juice, and vinegar, which shall be served out within ten days after salt provisions have been served out, the lemon juice or lime juice at the rate of one-half ounce daily, and the vinegar at the rate of one-half pint weekly, per man.

WATER SUPPLY.

The satisfactory storage of water aboard ships is a matter of some difficulty. Small vessels, as ordinary merchant ships and similar craft, not provided with distilling apparatus, must necessarily carry a sufficiency of water for the passage between ports, reckoned at three quarts daily per man plus an amount sufficient for cooking. Water is stored in wooden casks and metallic tanks. Storage in casks is far from satisfactory, on account of the deterioration which occurs in the quality of the water. This is due to the action of the water in extracting matters from the wood, and to decomposition of these matters induced and carried on by the usual agencies. Casks should not be made of soft wood, and the interior should be very thoroughly charred, in order to diminish as much as possible the extraction of soluble constituents and to guard against decay. Tanks are commonly made of galvanized iron, lined sometimes with cement. They should be placed in easily accessible locations which admit of ready inspection and cleansing.

No water should be taken on board unless its source is known and its quality is such as to preclude the danger of introducing water-borne diseases. Large vessels and steamships provided with distilling apparatus do not, of course, need to provide for the storage of large volumes of water. The water yielded by a distilling apparatus is, on

the whole, far superior in quality to that which, however good originally, has been stored for any considerable time. For full consideration of the subject of water and its storage, the reader is referred to the chapter devoted to that subject.

THE SAILOR'S SLEEPING QUARTERS.

The sailor is berthed commonly either in deck houses, forecastles, or between decks. Deck houses are by far to be preferred, since they are well lighted and can be well aired. They are placed about midships, and are most accessible and convenient. There are two kinds of forecastles; one, known as the top-gallant forecastle, has side lights and is entered through a doorway; the other, commonly found on merchant vessels and small craft in general, is entered from above through a hatchway, and is not lighted. This is the least desirable lodging place, and is exceedingly difficult to keep in a cleanly condition. In fact, on merchant vessels, it is commonly infested with bedbugs and other vermin, and is the storehouse for wet, dirty clothes and all manner of rubbish. Forecastles are likely to be damper than other parts, on account of the greater amount of water shipped over the forepart of the vessel when under way.

Cubic space per capita depends upon the facilities for the convenient hanging of hammocks; it can never be generous: it is always far less in amount than is regarded ashore as essential for the maintenance of a fair degree of health. In fact, sailors are almost always overcrowded: they have nothing like the allowance which obtains in barracks, but rather that of the tent in the field. The fact that the sailor's rest is broken in upon, so that at no time does he get more than four hours of consecutive sleep, may perhaps be a benefit to him in that, in the intervals, he breathes the pure outside air, and may thus, in some measure, counteract the evil results of breathing the necessarily impure air below. The English statute requires that a seaman in the merchant marine shall have not less than 72 cubic feet of air space and 12 square feet of floor space, exclusive of that occupied by the necessary articles of furniture and dunnage.

In the matter of cubic space, the crews of merchant vessels are, as a rule, better off than those of men-of-war, since, on vessels of the latter class, the complement of men required for all the various duties is so large that overcrowding is to be looked upon as a matter of course. The sleeping quarters of most of the crew are located below the water line on the berth deck. Some are quartered on the gun deck, which is above the water line, and consequently is circumstanced better as to light and air.

The sailor sleeps in either a hammock or a bunk. The hammock is a hanging bed, made of heavy canvas, about six feet long and half as wide. At each end, brass or copper eyelets are worked in, through which the nettles of the clews pass and are fastened. The clews end in an iron ring, to which the lashing for each end is attached. In the

hammock are placed a mattress and the necessary coverings, and on this he gets his modicum of rest in a constrained, unnatural position, bent into a curve, no matter how he may dispose himself. Bunks are far more rational and comfortable, since they permit of a horizontal attitude. They are made of iron framework, wound with canvas or other non-conducting material, or of wood. They possess the additional advantages of occupying less space and of being more easily kept in clean condition. Commonly, they are placed in two tiers and sufficiently far apart to permit of easy passage on either side. The lower tier should be not less than nine inches from the deck.

Quarters for officers and passengers are, as may naturally be supposed, more favorably located and more commodious than those assigned to the crew.

THE DISEASES OF SAILORS.

The chief diseases to which persons on shipboard are subject include diseases of the respiratory organs (particularly tuberculosis), rheumatism, diseases of the digestive apparatus, venereal diseases, and seasickness. Of nervous troubles, nostalgia, melancholia, and hypochondriasis are common. Skin diseases of various kinds are also common. Cholera and yellow fever and other important infectious diseases appear to be closely connected with ships, by which, as elsewhere noted, the contagion is frequently carried from one country to another. Formerly, scurvy was associated especially with life on shipboard, but since the discovery and introduction of the proper prophylactic remedy, the disease has been practically eliminated from the list. In addition, troubles of minor importance, arising from special duties, are of common occurrence, but not lasting in character; such, for instance, as eyestrain and other disturbances of vision, disturbances of hearing, and trauma.

In spite of improved hygiene, diseases of the lungs, particularly tuberculosis, appear generally to be on the increase among seafaring men, instead of on the decline. It is said that in the British Navy, between 1883 and 1890, diseases of the lungs increased 60 per cent. It had been supposed that the doing away with masts, sails, and rigging, with the consequent lessened exposure of the men to cold and wet, would have a contrary effect; but its influence, if any it had, has been more than counterbalanced by the change in conditions below, the men living now in a very crowded condition in hot steel ships.

Firemen and stokers are very prone to phthisis, and not infrequently the exhausting nature of their work causes them to become debilitated, morbid, and inclined to suicide. Among this class, vertigo, stupor, and convulsions are common.

Hospitals for the treatment of the sick at sea should not be located, as they usually are, on the berth deck forward, but should be about amidships, where they may receive a sufficient amount of light and air. The furniture should be of iron, thus permitting easy cleansing.

VENTILATION OF VESSELS.

The air of a ship below the deck is commonly far from meeting the requirements generally accepted, and is often extremely foul, and hence wholly unfit for respiration. The contributing causes of this condition are an excess of aqueous vapor from respiration and from water used in swabbing decks or shipped over the sides while under way; an excess of carbon dioxide from respiration, combustion of illuminants, and decomposition of organic matters; effluvia from the bilge-water, from oil, tar, paint, and other necessary supplies, from the components of the cargo, and from other sources. The crew's sleeping quarters, even though protected by all practicable means from contaminated air from the hold, bilges, and fore-peak, are commonly reached through some channel by the effluvia, which, mingling with those natural to the place, serve to make a very bad condition much worse.

The problem of efficient ventilation of vessels is exceedingly complex, and is quite different from that of ventilating dwellings and other buildings, since the fundamental conditions are so little in agreement; and it becomes more complicated with increase in the size of the ship. The principles are the same as in house ventilation, but the application of methods is surrounded by greater difficulties, due to peculiarities of construction and to external conditions. Natural ventilation may be effected under favoring conditions through the medium of hatchways, port holes, and other openings; canvas tubes or funnels with a side opening at the top, stayed to face the wind or the ship's course, known as windsails; fixed ventilating tubes acting in the same manner, hollow masts, and other appliances.

Hatchways are commonly the only openings for ventilating the lower forecastles, and in foul weather they are kept closed. Sometimes an outlet, capped by a cowl, is provided, but it is usually kept closed, on account of the discomfort of drafts. Deckhouses and top-gallant forecastles are much more efficiently ventilated through the side openings and because of their greater exposure to the external air. Holds and spaces between decks are ventilated through hatchways, fixed tubes, and windsails, hollow masts which act as ventilating flues, funnel casings which act like jacketed stoves, and other means.

Vessels of large size cannot depend upon any system of natural ventilation, but must have recourse to mechanical methods of propulsion and extraction, and even then only an imperfect result can be hoped for. As in the mechanical ventilation of buildings, propulsion is likely to prove far more effective than extraction, and its efficiency is very greatly dependent upon the intelligent planning of the system of the channelways and valves. Valves are required not only for the purpose of shutting off the air current where it is not at the moment required, but also, on men-of-war and other large vessels, for the protection of water-tight bulkheads in case of accident, and of different compartments in case of fire.

The ventilation of vessels engaged in carrying passengers is provided for in part by legislation. The U. S. Revised Statutes require that vessels carrying a hundred or more passengers shall have for each apartment two ventilators, one forward and one aft, of a capacity proportionate to the size of the apartments, a tube 12 inches in diameter being regarded as the proper size for an apartment for 200 persons. If other means of attaining the same measure of ventilation are provided, they may be used in place of those stipulated. Under the English law, the provisions for lighting and ventilating must receive the approval of the Emigration Officer at the port of clearance, and if there are as many as a hundred passengers on board, the vessel must be provided with "an adequate and proper ventilating apparatus to be approved by such officer and fitted to his satisfaction."

When artificial heating is required, use is made of stoves and steam heating. In the forecastle of sailing vessels, small square stoves of cast iron with a movable cover are employed. They are dirty, inconvenient, and generally unsatisfactory.

GENERAL HYGIENE OF SHIPS.

Of the very first importance in the hygiene of ships is general cleanliness of ship and personnel. Cleanliness of the ship requires constant watchfulness and unremitting attention, and daily inspection is necessary to insure that cleanliness is not wholly superficial, since it often happens that, whereas the decks and all visible portions are clean, parts which are out of sight are not in a wholesome condition. Naval vessels of all countries are, as a class, much more carefully looked after in this respect than those of the merchant marine.

In securing cleanliness, it is a mistake to use water too frequently and in too great abundance, and great care should be taken that all superfluous water is removed as quickly as possible from all parts below decks, since one of the cardinal directions is to keep dry, for damp ships are notoriously unhealthy. The dampness that condenses from the moist air upon the surface of metal plates and overhead beams is a source of great annoyance from its constant dripping, and keeps up a continual dampness. This can be remedied only by sheathing or coverings of non-conducting material, such as granulated cork or asbestos fiber.

The most difficult parts to keep in even fairly sweet condition are the bilges, in which collects that most disagreeable and offensive liquid known as *bilge-water*, the internal drainage of the ship, much of which, in wooden ships, leaks from without inward, through the seams. The disgusting odor of bilge-water is due to the decomposition of the organic matters present, and to the reduction of sulphates of the salt water to sulphides. The bilges require periodical pumping, and are connected for this reason with pumps, known as bilge-pumps. The bilge-water removed is discharged into the sea, and after removal,

the bilges are flushed with clean sea-water and again pumped out; sometimes they are regularly deodorized and disinfected.

Next in importance, on account of their commonly unwholesome condition and the difficulty with which they are made clean and kept so, are the peaks. In small vessels, the fore-peak very commonly causes fouling of the air of the crew's quarters in the forecastle.

From a hygienic standpoint, the stoke holds of steamers are of great importance, for here, in a very restricted space, exposed to excessive heat from the furnaces, the stokers perform their exhausting office. The air of the stoke holds is commonly not only excessively hot, but exceedingly foul, and these conditions can be abated only by proper ventilation, which may be secured either by means of mechanical appliances or windsails.

Water-closets and latrines should be of as simple a type as possible and capable of effective flushing. The soil-pipes may discharge above or below the water line. Where closets must be located below the water line, special pumping arrangements are provided for their emptying and flushing. Their placing differs according to the size and character of the ships. Latrines for the crew are placed forward and completely disconnected from the forecastle. They are supplied at the rate of not less than three for every hundred men. Urinals are commonly a source of great nuisance, and hence require extra care.

On passenger ships, three closets should be provided for every hundred persons carried, and they should be so located with reference to sleeping quarters that they may not give rise to nuisance.

Whenever weather and other circumstances permit, all bedding should be thoroughly aired, each article being brought up from below and exposed separately, fastened to the rigging or upon the girt lines. Hammocks should be thoroughly cleaned and dried about once in every fortnight. Blankets should be washed with soap at least every six months; hammocks and all articles of bedding should be, when practicable, exposed for part of each day to the direct action of the sunlight.

For methods of disinfection and general cleansing, the reader is referred to the chapter on Quarantine.

Personal cleanliness of the men is of even greater importance than cleanliness of their surroundings, and, indeed, the two go hand in hand, for men of cleanly habits will not permit their surroundings to be otherwise than wholesome, and those who are not naturally so inclined should be required to keep themselves clean. Each man should be allowed a sufficient supply of fresh water daily, and the necessary appliances for washing should be provided. In navies, the washing of the person is commonly made a part of the routine. Special provision for the care of the person is required for those who have the dirtiest work to perform, namely, the firemen and stokers, since their occupation precludes the use of much wearing apparel, and the air of

the place where they work is laden with coal dust and so hot that their bodies are constantly bathed in perspiration. Short bath-tubs of galvanized iron, a sufficient number of wash-basins, and a reasonable allowance of water and soap, should be provided. Given the conveniences and encouragement to make use of them, the chances are that they will be appreciated and freely used.

As is the case with soldiers, it is of very great importance that sailors should be kept busy and, at the same time, should have sufficient time for relaxation, which they should be encouraged to spend in such pursuits as will conduce best to the promotion of cheerfulness and the prevention of ennui.

CHAPTER XI.

TROPICAL HYGIENE.

THE SOLDIER AND THE CIVILIAN IN THE TROPICS.

THE following pages, dealing with hygiene in the tropics, have greater general applicability to the life of civilians, who have a wide choice in their mode of life and distribution of their time, but the main principles are equally applicable to the life of the soldier, even although his liberty of action in the following of his own inclinations is very greatly restricted.

It is a very common mistake among persons reared in temperate climates to suppose that the change to a tropical climate means chiefly a sudden access of heat, and that it is simply this increased heat which one has to consider; but it is not, as a rule, the actual temperature which affects the individual, for in the North we may have for days at a time a higher temperature than obtains customarily in some parts of the tropics, without suffering in the same way. The principal difference lies in the excessive tropical humidity, but tropical climates are not equally humid, some being exceedingly moist, and some exceptionally dry.

In some parts of Australia, for example, the climate is exceedingly dry and the temperature is very high, and yet there is much less liability to sunstroke and heat apoplexy than in some parts of India, where the temperature is less high, but the atmosphere exceedingly humid. Since all hot climates are not alike, the mode of life also varies; and in any case it is necessary to take into consideration the special local characteristics of climate and the methods of life followed by the natives, and if one takes care to adapt his clothing, his diet, and personal habits to the conditions which surround him, life in the tropics may be bearable, even if not thoroughly enjoyable. On this point, Dr. S. O. L. Potter, U. S. V.,[1] writing on the spot, says: "If people can take reasonable care of themselves, and do not give way to excesses in any form, drink, eating, or working, they will live as healthily in Manila as in New Orleans or St. Louis or New York." But they cannot withstand the effects of any tropical climate for long without an occasional visit to the temperate zone, for prolonged residence brings about an undoubted deterioration of the system in spite of all possible care.

According to Freeman,[2] Europeans, after some years' continuous residence in a hot country, degenerate, losing energy, initiative, and memory, which, from a military point of view, is not compensated for

[1] Notes on the Philippines, Philadelphia Medical Journal, April 7, 1900 p. 803.
[2] The Sanitation of British Troops in India, London, 1899.

by diminished liability to disease. Hence the necessity of furloughs at stated intervals. Potter says, "Many of our older officers have undergone a process of rapid aging here without any definite ailment to account for their condition. They simply grow thinner and thinner day by day, running down gradually in physical strength as emaciation goes on, until finally the General takes pity and sends them home."

According to a number of observers, the body temperature of new arrivals in hot climates is appreciably elevated (0.4–0.9 degree F.) above the normal, and under some conditions of high temperature, since the body cannot radiate heat to hotter surrounding air, the body temperature may run as high as 102° in health. The body is then dependent chiefly upon evaporation from the surface for the keeping down of the temperature as nearly as possible to normal. But when high temperature is conjoined with high humidity, the difficulty and discomfort are much increased. Continued moist heat, through its influence on metabolism and the various functions of the body, causes great nervous exhaustion and general deterioration. The respiration is depressed, the force and rate of the pulse lowered, the mind becomes dulled; the sweat is doubled in amount, and thirst increased in proportion; the digestive function is weakened, and appetite for even the lessened necessity for food is diminished and requires constant stimulation. The body loses in weight, and both body and mind in energy.

Dr. Federico Montaldo, of the Spanish Navy, in a practical handbook[1] written for the use of Europeans intending to visit the Spanish colonies, published just prior to the outbreak of our war with Spain, urges upon those who are not sure of the soundness of their health the necessity of submitting themselves for thorough physical examination, since a trivial ailment, easily corrected at home, may develop in the tropics into a trouble not easily managed. Potter,[2] also, on this latter point, remarks: "It is all very nice as long as one is well, but those who get sick don't easily recover here. Convalescence is very slow and very difficult." And again, "the general climate of these islands is not pernicious for those who are able to avoid exposure, but when broken down by hardship or incidental disease, complete recovery is doubtful and convalescence is very slowly established." Burot and Legrand,[3] also, lay stress on the necessity of selection of healthy individuals for service in the tropics, saying that if the soldier is too young or if his constitution is not strong, he will be an easy prey to disease, while if, on the contrary, he has been carefully selected in the light of the peculiar conditions and the demands upon his strength, he will be better able to resist morbid influences.

Dr. Lucca,[4] speaking from an experience of a number of years as a military surgeon in Borneo, urges the exercise of great care to insure the health of troops on transports, so that they may not be landed

[1] Guia Practica Higiénica y Médica del Europeo en los Países Törridos (Filipinas, Cuba, Puerto Rico, Fernando Póo, etc.), Madrid, 1898, p. 19.

[2] Loco citato.

[3] Hygiène du Soldat sous les Tropiques, Paris, 1898.

[4] Einige Bemerkungen über Acclimatisation und Leben in den Tropen, Munich, 1898.

already sick and weak and ready for shipment home. Rasch[1] advises all who are prone to nervous disorder, those already suffering, and, above all, epileptics, to keep away from the tropics; and Macleod[2] offers the same advice to anyone whose heart and blood-vessels are not wholly normal.

It is also well to choose, if possible, the best time of year for landing. There are, it is true, only two seasons in the tropics, the dry and the rainy; but there are, nevertheless, transition periods of greater or lesser duration.

Residence.—If one has a choice in the matter of residence, it is well to be cautious in its exercise, and to begin on high land and away from the coast. The English have long recognized the necessity of sending their soldiers inland and to the hills, when military requirements are not opposed. After getting somewhat accustomed to new conditions, the lower parts and the coast may gradually be ventured upon.

In some parts of the tropics, it is customary to leave sleeping apartments open during the day and closed at night; but in others, the contrary is the rule, the doors and windows being closed by day. The best form of bed is that made of not too heavy iron, with a frame or other device to support a mosquito bar. The bed should be placed away from the walls and out of draughts. The legs should stand in small vessels filled with water, in order to keep away small crawling insects. If in the country and neither bed nor hammock is to be had, and one is obliged to sleep on the floor or ground, a rubber or other waterproof sheet or a dressed hide should be spread, and the body should be well protected against condensing moisture and troublesome insects.

Habits of Life.—All authorities agree in at least one particular, and that is, in urging moderation in all things—diet, drink, work, exercise, dress. The diet should be chosen with care, and iced drinks taken in great moderation, if at all. The clothing should be chosen with judgment, both as to protection from the heat of the sun and against chilling of the body.

Work should not be excessive, nor should it be performed in the sun during the hottest part of the day. Montaldo[3] advises one to rise with the sun and take a quick cool bath, and then, after a light breakfast of coffee, tea, or chocolate, with a little bread, to attend to whatever duties one has to perform, until about 10.30 A. M., when luncheon may be had. This should not be heavy as to food or drink. The latter may consist of a little water with claret or lemon juice, or tea or coffee. If one's work is out of doors, it should not be resumed before 3 in the afternoon, and in the meantime one should rest indoors. After 6.30, a substantial, but not too hearty, dinner should be taken, observing the same moderation in the matter of drinking. One should never go out with an empty stomach nor do work immediately after a

[1] Allgemeine Zeitschrift für Psychiatrie, 1897, p. 745.
[2] Journal of Tropical Medicine, Vol. I., No. 1.
[3] Loco citato.

meal. After dinner, a walk or some form of recreation until 10.30 or thereabouts, which is the proper time for retiring.

One is advised strongly not to expose one's self to the cool external night air; to avoid cold bathing and cold drinks while perspiring; and especially to avoid standing for a long time in the shade in garments wet with perspiration. If one is compelled to be exposed to the sun for long, the protection afforded by umbrellas and colored spectacles against heat and glare should be sought. The consequences of exposure may be exceedingly severe or even fatal. There are various forms of what are commonly known as sunstroke and heat apoplexy. A very common form is one of syncope, brought on by overexertion in the direct sunlight or even within doors by one already in a depressed condition. The skin is moist and clammy, the pulse very feeble and almost imperceptible, the muscular power almost completely lost. Death may occur by cardiac failure, but recovery under appropriate treatment is the general rule. Another form, due to direct action of the sun's rays on the brain and cord, is in the nature of a very sudden severe shock affecting the respiratory and cardiac centers, and commonly quickly fatal. Complete recovery is rare. A third form, commonly known as heat apoplexy, is due to exposure to constantly high temperature not necessarily involving direct exposure to the sun, and, in fact, may occur in cloudy weather and at night. The whole body becomes overheated and the temperature may exceed 110° F. The skin is generally dry, although sometimes moist; the pulse full and regular or small and irregular; respiration labored. There is intense restlessness, and epileptiform convulsions may supervene. These cases are frequently fatal, and if recovery occurs, it is not complete. In India, according to Freeman,[1] heat apoplexy and sunstroke occur usually toward the end of hot weather, although the midday sun is strong enough in most places to cause severe headache, if not sunstroke, the year round.

For the avoidance of sunstroke, in addition to having proper head covering and umbrella, the neck and spine should be properly protected from the sun's rays. The double pleat in the back of the Norfolk jacket is intended as a protection to the spine. A few green leaves in the hat are sometimes conducive to comfort.

The commonly given advice to follow the customs and habits of the natives in respect to diet and physical exercise can be accepted only in part, for the native of the tropics is, as a rule, a lazy individual who merely exists; the wear and tear of his system require but little in the way of repair, and his food is of the simplest kind; he has no ambition and no desire to hoard up a fortune which he cannot use; but between his indolence and our high-pressure life, there is a happy mean, especially in the tropics.

Diet.—The question of diet in the tropics is a very serious one, for errors may be followed by disastrous results. Since prolonged heat exerts an unfavorable influence on digestion, this function should not

[1] Journal of Tropical Medicine, Vol. I., No. 1.

be made to bear too heavy a burden, and it becomes necessary to restrict the diet in several particulars. No more food should be taken than can comfortably be digested, for both dysentery and diarrhœa are favored by the irritation caused in the intestines by food partially digested or undergoing fermentative processes. But the change from the accustomed diet should not be made with too great abruptness.

The natives depend chiefly upon a vegetable diet, in which rice and beans and fruits of all kinds play prominent parts. Meat, if eaten at all, is taken usually in very small quantities. As a rule, in hot climates, it is not tender, for it cannot be hung days and weeks, as with us, to ripen, but must be cooked and eaten within a very few hours after slaughtering. Fish should not be used unless very fresh, and shell-fish of all kinds should be avoided. Fresh milk is ordinarily not to be had or, at least, is difficult to obtain. It speedily sours and becomes unfit to drink. Condensed milk of good quality is more to be depended upon. Vegetables should be thoroughly cooked, or they will seriously tax the digestive organs. Fruits should be perfectly ripe and sound; over-ripeness is quite as objectionable as greenness. Over-indulgence in fruit, even of the best quality, and especially in the sour fruits, is particularly to be avoided.

Tea, coffee, and chocolate are advised in moderation. Lime juice with water or cold tea makes a most refreshing drink. Tamarinds in water are also most grateful.

If alcohol in any form is desired, the light wines diluted with water are recommended more highly than beer. Spirits are generally condemned, but there appears to be no valid reason why, when very largely diluted with water or soda water, they should exert a more pernicious influence than wine only moderately extended. In any event, alcohol should be taken only with food.

The Use of Alcohol in the Tropics.—Writers on tropical hygiene are almost unanimous in the opinion that, whatever may be said for and against the use of alcoholic drinks in other climates, their use in the tropics constitutes a distinct danger, and that much of disease commonly attributed to climate is due actually to alcohol. Especially is this true of the various renal and hepatic troubles. According to Treille,[1] the *abuse* of alcohol is the chief cause of the frequency of diseases of the liver, not alone among visiting Europeans, but among natives as well.

Dr. Chr. Rasch,[2] speaking of the futility of talk about Europeans getting accustomed to continued high temperature with high humidity, and describing the various steps in physical and mental deterioration, to counteract which, one turns to alcohol and other stimulants, says that these, together with insomnia and enforced lack of exercise, bring about a general atonic condition, or, in other words, a lowered physiological resistance to diseases in general. Dr. Breitenstern,[3] who for

[1] Principes d'Hygiène coloniale, Paris, 1899, p. 272.
[2] Allgemeine Zeitschrift für Psychiatrie, 1897, p. 745.
[3] Hygiene in den Tropen, Monatsschrift für Gesundheitspflege, 1898, Nos. 7 and 8.

twenty years served as an army surgeon in the Malay Archipelago, gives it as his opinion, based on long observation, that total abstinence from alcohol is far preferable to even the most moderate indulgence.

A writer in Manila has pointedly remarked concerning the health of the American troops, "It is not so much the climate as the glass bottle which injures people out here," which statement is corroborated by another who had seen actual service as a member of a company, many of whose members were total abstainers and the rest made up of moderate drinkers and those prone to excesses, the latter constituting 20 to 25 per cent. of the whole. Of the latter class, only two returned home in approximately the same condition of health which they enjoyed at the time of enlistment. Of the moderate drinkers who confined themselves to malt liquors, a large majority suffered more or less impairment of general health. But the total abstainers returned almost to a man in excellent health, having endured the same hardships of an active campaign. The same correspondent, speaking of the far greater harm induced by the stronger alcoholic drinks, relates that he had repeatedly seen American soldiers, after spending several hours under shelter, drinking round after round without perceptible harm, fall over with all the symptoms of sunstroke as soon as they stepped into the glaring rays of the hot sun.

On the other hand, in opposition to the general opinion adverse to even the moderate use of alcohol in the tropics, Dr. C. E. Woodruff,[1] U. S. A., after a careful survey of the conditions obtaining in the Philippines, declares that he would change the statement in the general order from headquarters of the army, July 2, 1898, "The history of other armies has demonstrated that in a hot climate abstinence from the use of intoxicating drink is essential to continued health and efficiency," to "Experience has demonstrated that in a hot climate the moderate use of intoxicating drink is essential to continued health and efficiency." He asserts that the almost universal drinking must mean a natural defensive craving occasioned by the terrible nervous exhaustion, a true neurasthenia, due to long-continued exposure to great heat and atmospheric humidity, indicating that waste is greater than repair. He asserts that men who want no alcohol at home have this defensive craving for it in the Philippines, and cites Spanish authority that a daily ration of wine has been found necessary. Whiskey, when sufficiently diluted, is the equivalent of wine, and the Scotch variety is regarded by him as superior for the purpose to American, which soon occasions nausea. Beer, by reason of being conducive to colic, diarrhœa, headache, loss of appetite, and general distress, he regards as distinctly harmful. While advocating the *moderate* use of alcohol, he believes that the results of abuse are far more serious than at home.

Concerning beer in the tropics, there is much divergence of opinion, some regarding it as a valuable safeguard against abuse of stronger

[1] Philadelphia Medical Journal, April 7, 1900, p. 768.

alcoholics, others agreeing with Woodruff that it is harmful. It is said that the drinking of much beer followed by heavy sleeping predisposes to sunstroke and heat apoplexy.

Clothing.—One is advised to take plenty of light cotton, linen, and merino underwear, a generous assortment of trousers and coats of white duck or flannel, and light merino stockings. High boots, well oiled and with hob-nails, laced boots, leggings of cloth and leather, and light footwear for indoor and city use should be included. Light waterproof outer garments with cape and hood are recommended, and for protection against the sun, white umbrellas lined with blue or green material, and spectacles with green or blue colored glasses.

The head-covering should be selected with the double consideration of comfort and protection for the head and neck. The material of which it is made should be chosen with regard to local climatic conditions. In a particularly dry hot climate, for instance, pith is the most suitable material, being lighter than either cork or felt; but a hat made of this material is absolutely worthless in a wet climate, since on being exposed to rain it absorbs water, becomes exceedingly heavy therefrom, and is reduced to a worthless, shapeless pulp. Hats should be properly ventilated in the crown, and there should be a generous space for the free passage of air between the head-band and the inner side of the hat; that is to say, the head-band should be fastened to the crown of the hat at only a limited number of points and with intervening small pieces of wood or other material, so that the band shall keep its proper shape. All head-covering of whatever form should afford proper protection for the sides of the head and the ears, as well as for the front and back. A puggery affords additional protection.

The brim of the head-covering should be lined with some material of a bluish or green color, as a relief to the eyes. The outside should be light in color. The head-band is made of leather, and is easily saturated with perspiration, and then hardens on drying; while it is wet, it is exceedingly uncomfortable. If covered with fine flannel, it will be found to be much more comfortable.

Jackets and other outer garments should afford perfect freedom of action in both riding and walking. The Norfolk jacket is a favorite form, and may be made of duck, khaki, or similar material. It is well to leave a few inches of the arm-scyes unstitched for the sake of ventilation. For shirts, a mixture of silk and wool, known as kashmir, is regarded as the best material, being very light in texture and perfectly absorbent. Gauze undershirts with short sleeves, or with no sleeves at all, should be worn beneath the shirt. Elastic cotton and jean are the best materials, so far as comfort and durability are concerned, for drawers.

If one is to do much riding, it is advised that as much care be expended in the selection of a saddle as in selecting boots, since comfort in horseback riding in the tropics is very largely dependent upon the fit of the saddle.

Care of the Person.—The irritating effect of hot winds, which frequently carry fine particles of sand and dust, and the glare of the sun, which conduces to troubles with the eyes, should be guarded against. Not infrequently the ears, too, are affected injuriously by hot winds, but they are easily protected by external coverings or by cotton-wool plugs. The nose and lips are subject to cracking and uncomfortable dryness, which may be helped by cold cream or some similar application. The nails should be kept closely pared, since they become brittle and crack off.

The skin, having a very important function to fulfil, should be kept thoroughly clean, if on no other account; but bathing in too cold water or for too long a time should be avoided. Parasites abound in tropical climates, and should be looked for on the person and removed with all care. Among these may be mentioned the chigœ, or jigger, an exceedingly troublesome small flea (*Sarcopsylla penetrans*) which burrows beneath the skin, particularly of the feet, and beneath the nails. At first, it causes only itching, but if not then removed, sharp pain and inflammation ensue. A half teaspoonful of flowers of sulphur inside the shoe is said to be an efficient preventive. Another parasite of far greater importance, especially to the troops in the Philippines, is that which occasions the dhobie itch, which can be avoided only by very great attention to personal cleanliness and frequent changing of underclothes. It first attacks the perineum and axillæ, and when the acute stage passes by and the inflammation somewhat subsides, the scales become rubbed off and reach the feet, where the trouble spreads rapidly, causing intense itching with consequent scratching and the evil consequences thereof.

Diarrhœa and constipation are alike to be avoided. The former should be checked at once, and should on no account be allowed to continue without treatment. It is easily brought on by improper or ill-cooked foods, impure water, green and over-ripe fruit, sudden changes in the weather, and intemperance. Constipation should be avoided by the acquirement of a regular habit. Sometimes, a cup of tea or coffee on rising will act beneficially, and oatmeal and coarse bread, figs and prunes may be found to assist, but purgatives and enemata should be avoided, if possible to get along without them.

Tropical Diseases.—It is beyond the scope of this work to enter upon the field of tropical medicine, but it may be said, in general, that the diseases of hot climates are exceedingly varied. Some of them are peculiar to certain districts; some are exaggerated forms of what we in the temperate zone regard as simple maladies. In general, it may be said that in the tropics one meets nearly all the diseases of the temperate zone plus a great variety of others, but some of our most common diseases may be very rare in certain places. Thus, scarlet fever and diphtheria are rare in the tropics as a whole, tuberculosis is rare in parts of India and common and quickly fatal in other parts of the tropics. Rabies is more common in India than in England, and the victims are almost always Europeans. Leprosy, beri-beri, and

elephantiasis are common among the natives, but very rare among Europeans.

Throughout the tropics, dysentery kills many more people annually than cholera, and works greater havoc in armies than the contending forces. Typhoid fever always appears sooner or later in camps of soldiers from temperate climates, and the new arrivals are commonly observed to be the most susceptible. This disease and cholera, according to Freeman, rarely occur in India during the hottest months, when the burning rays of the sun act as a germicide; but when the rains come and sweep the accumulated surface dirt into the water courses, they quickly appear.

For a most interesting description of the diseases observed in the tropics, the reader is referred to Dr. Patrick Manson's *Tropical Diseases* (second edition, 1900).

CHAPTER XII.

THE RELATION OF INSECTS TO HUMAN DISEASES.

ALTHOUGH a supposed relationship between insects and the spread of diseases has been considered in greater or lesser detail by writers of all times, it is only within the most recent years that the possible connection has been regarded as entitled to most serious consideration. It is not strange that the bare statements of ancient writers concerning the influence of flies and other insects as disseminators of plague and other diseases were not received with any degree of credence, for until recent advances in the fields of bacteriology and zoölogy made demonstration of the connection possible, there was no more reason for accepting them than for accepting similar unsupported assertions concerning the action of clouds and things supernatural. But as our knowledge of the exciting causes of diseases grew with bacteriological and zoölogical research, so, also, came an appreciation of the fact that these same causes might be disseminated by insects and other lower forms of animal life.

Disregarding the not infrequent reports of sickness and death attributed to insect-bites, which, so far as one may know, may have become secondarily infected, it may be said that serious attention was not drawn to insects as bearers of infection until the early 90's. And although Nott, in 1848, had suggested the mosquito as a cause of malaria and yellow fever, and Finlay, in 1881, had asserted that the latter disease was transmitted from infected to non-infected man by these insects, it was not until the closing years of the century that these theories were demonstrated as correct.

The insects which have been most extensively studied are, naturally, those which have the greatest opportunity for contact with human beings, namely, flies, fleas, bedbugs, and mosquitoes; but others have been the subject of more or less extensive investigation which has demonstrated their capacity for conveying, externally or within their bodies, virulent bacteria of many kinds. That insects, coming in contact with material containing pathogenic bacteria, may convey the same directly to wounds or food-stuffs upon which they may alight, needs hardly to be demonstrated, whether the organisms are adherent to the body, limbs, or proboscis; but how long the bacteria may retain their virulence during carriage, and whether, if taken into the insect's alimentary canal, they can survive the process of digestion and be discharged in the fæces, can be determined only by direct experiment; and it was with such problems that the first researches on the agency of insects in the transmission of disease were engaged. It has been

found that certain species of bacteria are digested by certain insects; but it must be borne in mind in practice that this should not be accepted as the inevitable or even usual result, for although flies, for example, will digest certain bacteria, they cannot always be depended upon to do so, and may excrete them with other undigested food.

Besides transmitting specific bacteria, the insect world is responsible for the spread of parasitic organisms belonging to the animal kingdom, now recognized as the causes of malaria, filariasis, and yellow fever, as will be shown.

FLIES.

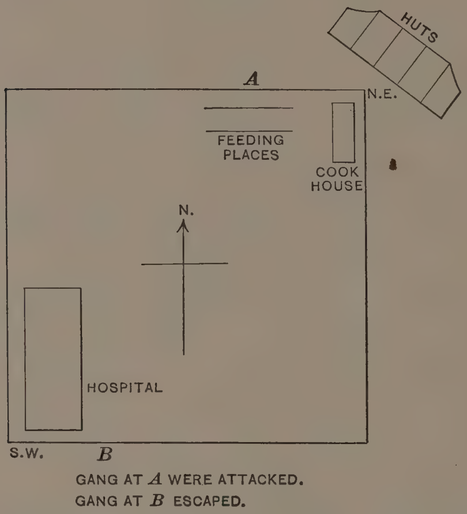
Although the possibility of the spread of such diseases as cholera, dysentery, and typhoid fever was demonstrated as early as 1892, the matter did not receive particular attention until the unusual prevalence of typhoid fever in the great military camps in the South in 1898 was made the subject of a careful inquiry, which led to the conclusion that the great swarms of flies which infested the camps were largely responsible. A series of interesting experiments on the subject of infection through the agency of flies was conducted by Sawtchenko[1] with pure cultures of cholera bacilli. The bacilli, fed to two kinds of flies, were found in the excreta and bowels as late as four days after ingestion; removed on the third day and inoculated into guinea-pigs, they were found to be as active as the pure cultures themselves. Similar results were obtained when, instead of pure cultures, the discharges of cholera patients were employed as feeding material. Some of the experiments indicated that the bacilli probably multiply within the fly, which thus acts as a breeder and distributing agent at the same time. A fly, caught in the autopsy room at Hamburg during the great cholera epidemic of 1892, was examined by Simmonds,[2] and yielded numerous bacilli. This suggested an inquiry into the length of time the poison could retain its activity when adherent to flying insects, and experiment showed that it remained virulent for at least an hour and a half after drying. Surgeon-General Sir William Moore[3] drew attention, in 1893, to the fact that, in India, flies abound most extensively during the time and season of greatest prevalence of cholera; he suggested that they might act as carriers of typhoid fever, phthisis, and ophthalmia. He instanced an epidemic of anthrax spread by flies which had covered the carcass of a dog thrown into a ditch. It appears that the specific bacteria of this disease resist the digestive process, and may, therefore, be deposited from the external surface or in the fæces. According to Nuttall,[4] who was the first to present from the exceedingly scattered literature a general view of the part played by insects and other low forms in the transmission of human and other diseases, flies do not convey anthrax by biting, but may become crushed upon the skin, and thus convey the organism to the wound. From a

[1] Centralblatt für Bakteriologie und Parasitenkunde, XII., p. 983.
[2] Deutsche medicinische Wochenschrift, 1892, No. 41.
[3] Medical Magazine, July, 1893.
[4] Johns Hopkins Hospital Reports, VIII. (1899), Nos. 1 and 2, p. 1.

study of the cases cited, it appears likely that in many instances the specific organism may have been present on the skin prior to the advent of the fly or other insect.

An instance of strong presumptive evidence of an outbreak of cholera through the agency of flies is furnished by Buchanan,[1] who relates that in June, 1896, 9 cases of the disease occurred in Burdwan jail, where, prior to and after the attack, there was exceptional freedom from bowel complaints. The water supply was above suspicion and was the same for all the inmates, who numbered 190, and were divided into two groups, the ordinary prisoners and the "infirm gang." The latter worked, slept, and associated generally with the former, but their food was cooked specially, and they were fed in a separate place in the hospital compound. The ordinary prisoners—and it was among these that

Fig. 99.



Plan of grounds of Burdwan jail, where cholera is supposed to have been carried by flies.

all the cases occurred—had their food prepared and were fed at the extreme opposite corner, diagonally from the hospital. Over the wall at their corner were a deserted compound, and a row of dirty huts where cholera had existed during the preceding year. At the time, the city was more than usually infested with swarms of flies, and just before the outbreak, a storm had occurred, during which a strong E.N.E. wind blew across the jail yard from the locality mentioned. All who were seized were among those who were known to have had their evening meal in the corner during the storm, and it was believed that swarms of flies were blown from the huts, and on reaching the trees and corner of the high jail wall, obtained shelter from the storm and settled upon the food exposed in the plates before the gang. The accompanying figure shows the relative positions of the two gangs at

[1] Indian Medical Gazette, March, 1897.

their meal, and of the compound and huts from which the flies were supposed to have come. The evidence here is purely circumstantial, but it is to be noted that all of the sick belonged to the same gang; that all had been more than a month in jail, excepting 2, who had been there seven and twelve days respectively; that there had been no prevalence of diarrhœa before, during, or after the outbreak; that the water and milk supply were the same for all, and that the outbreak was very limited in extent.

The ability of flies to infect food was well demonstrated in 1892 by Uffelmann,[1] who allowed a cholera-infected fly to drink from a glass of sterile milk, and then shook the latter and kept it at 70° F. for sixteen hours, at the end of which time each drop contained about a hundred organisms.

The prevalence of typhoid fever among Europeans in India has been attributed by Surgeon-Major Battersby[2] to the agency of flies, since, year by year, outbreaks occur which are most difficult or impossible to trace to a water-borne cause, the water supply being in many instances above suspicion, and even of exceptional purity. During our war with Spain, investigation of the great prevalence of typhoid fever in the large camps in the South showed the abundant opportunity which exists for infection by flies, and demonstrated the necessity of thorough camp sanitation, and of excluding them from contact with both excreta and foods. Visiting the "sinks" at one time and the mess-tables at another, they have the widest opportunity for spreading infection.

The presence of plague bacilli in the intestines of flies has been demonstrated repeatedly within recent years, first by Yersin in 1894, who, noting the large number of dead flies where the victims were being autopsied, crushed one fly and inoculated it into a guinea-pig, which died of the disease in forty-eight hours. Further investigation showed the bacilli present in the intestines of the living fly, and led to the conclusion that they actually multiply therein. Nuttall[3] proved that flies may carry the disease, and that they themselves die of it. It is interesting to note that the statements of early writers to this effect were, therefore, correct. Most of these were vague, and gave no intimation of how the contagion was carried; but a Venetian, Mercurialis, in 1577, wrote (*De Pestilentia*) that flies go to infected houses, alight upon the sick, and then convey the contagion to other houses and deposit it on bread and other foods.

That flies may play a part in the spread of tuberculosis, too, seems probable, for the specific bacilli have repeatedly been found in virulent condition both in their intestines and in their excrements. They are believed, also to carry leprosy and various conjunctival diseases.

The larvæ of the common house-fly are sometimes found in the alimentary tract. Thus, Cohen[4] reports finding them in the dejections

[1] Berliner klinische Wochenschrift, 1892, p. 1213.
[2] British Medical Journal, August 10, 1895.
[3] Centralblatt für Bakteriologie, etc., XXII. (1897), No. 4, and XXIII. (1898), No. 15.
[4] Deutsche medicinische Wochenschrift, March 24, 1898.

of a nursing infant, the ova having probably been deposited in its mouth; and Bachmann[1] found them in the vomitus of a hard drinker, and later, after the administration of an infusion of pyrethrum, in large numbers in his fæces.

Flies may also transport the eggs of *Tœnia solium, Tricocephalus dispar, Ascaris lumbricoides*, and other parasites, and deposit them on foods.

FLEAS.

In 1898, Simonds[2] advanced the idea that fleas from rats sick with plague might spread the disease to other rats, and even to man. He found the specific bacilli in such fleas, as did also Ogata.[3] But Nuttall[4] has shown that fleas do not inoculate bacteria when they bite, but by sucking remove any already present at the point of application. His experiments were made with fleas found on mice sick with anthrax and mouse septicæmia, and then transferred to healthy mice. The results were negative. In other experiments, fleas were placed upon healthy mice from which the hair had been shaved in spots, whereon anthrax bacilli were smeared. Individual animals bitten by as many as eight fleas failed to become infected. Inoculation into healthy animals of the organs of fleas infected with anthrax, mouse septicæmia, and chicken cholera eight hours after infection gave negative results. He concluded that infection by fleas can occur only when the person bitten slaps and crushes the insect, and then scratches the spot. Simond's paper was assailed by Bruno Galli-Valerio,[5] who contends that Simond failed to distinguish between the flea which attacks man and that which infests rats and mice. Of 48 species of common fleas, 6 infest rats, and of these, but 2 will bite man. One of the latter (*Pulex serraticeps*) is not common on rats, and the other (*P. erinacei*) will not bite readily.

Nuttall[6] speaks of the possibility of transmission of *Tœnia cucumerina* through fleas. The adult worm is found in dogs, occasionally in cats, and rarely in man. The larval stage is found in dog fleas and lice, and even in the flea that infests man (*P. irritans*); but the dog flea is the usual host, and may carry as many as 50 larvæ. Dogs infest themselves by devouring their fleas and lice, and children may become infested by playing with and kissing dogs, the vermin being unconsciously swallowed. The larvæ are liberated in the intestine through digestion of the body of the insect, and they then exvaginate and take on their definite form.

BEDBUGS.

But few cases of transmission of disease by bedbugs are known. Nuttall quotes Dewèvre's[7] report of a case of transmission of tuber-

[1] Deutsche medicinische Wochenschrift, March 24, 1898.
[2] Annales de l'Institut Pasteur, XII., p. 625.
[3] Centralblatt für Bakteriologie, etc., XXI., p. 769.
[4] Ibidem, XXII., p. 625.
[5] Ibidem, January 6, 1900.
[6] Johns Hopkins Hospital Reports, VIII., Nos. 1 and 2.
[7] Revue de Médecine, XII., 1892, p. 291.

culosis after disinfection of a room in which a young man had died of the disease. After the process was completed, the room and bed were occupied by a brother of the deceased, and he, too, died. Investigation showed his body to be much bitten by bedbugs, and the bed to be swarming with the vermin. At this time, the floor was soiled with sputum, and had not been cleaned for many weeks. The contents of 30 bugs were inculated into 3 guinea-pigs with positive results: all died of tuberculosis. Virulent bacilli were obtained from 60 per cent. of the bugs examined.

Nuttall's experiments with bedbugs were, as with fleas, negative in results. Allowed to bite animals dying with or dead from anthrax, chicken cholera, and mouse septicæmia, and then transferred to healthy mice, they caused no sickness, although 10 mice were bitten by 136 infected bugs. The dejections of those fed on anthrax blood contained living bacilli only during the first twenty-four hours after feeding. Inoculations with their viscera, however, were uniformly successful, and it is probable, therefore, that infection may occur when the bug is crushed where it is biting. Mühling[1] agrees that no danger of infection is to be apprehended from either bedbugs or leeches, both of which suck without introducing anything into the wound, and will do no harm so long as they are not crushed.

MOSQUITOES.

Certain genera of mosquitoes have been definitely proved to be the intermediate cause of several of the most disastrous human scourges, and their connection with others has been suggested, and may at any time become demonstrated. The diseases which have been definitely connected with these pests are malaria, yellow fever, and filariasis.

Mosquitoes appear to be ubiquitous; they are found not alone in the torrid and temperate zones, but in the arctic regions, where, according to good authority, they are, in their season, even more of a pest than in warmer latitudes. In Siberia, they hibernate under the moss; and in all inhabited places they hibernate in cellars, outhouses, and other retreats. The larvæ, also, may hibernate, being frozen in the ice on the approach of winter, and able, when thawed out, to resume growth. Gorman[2] found living larvæ in water beneath ice at Providence, R. I., in December; and Wright[3] found *Anopheles* larvæ beneath ice in Aberdeenshire. Nuttall has known larvæ to live from seven to eight months. The adult mosquito may be found in the open, even when the weather is wintry. Thus, Sterling[4] saw mosquitoes at Mackinaw in March, 1844, when snow covered the ground to a depth of two to four feet. But it is only in warm weather that mosquitoes appear to have any part in the transmission of disease, for temperature has very great influence on the life and development of the parasites

[1] Centralblatt für Bakteriologie, etc., XXV., p. 703.
[2] Journal of the Boston Society of the Medical Sciences, V., p. 330.
[3] British Medical Journal, April 13, 1901, p. 882.
[4] Insect Life, III., p. 403.

which they spread, and upon their own activity and inclination to bite. The parasite of the tropical æstivo-autumnal type of malaria, for example, will fail to thrive in a temperature not too low for that of the tertian; and the latter will not live at 65° F., which temperature is not too low for that of the quartan type. Malaria rarely develops below 59° F., and is completely checked at 32°, at which temperature mosquitoes are very sluggish and do not bite.

We have in this country, according to Dr. L. O. Howard,[1] 9 genera of mosquitoes, represented by about 24 species, the larger number of which belong to the genus *Culex*, and are quite harmless. We have 3 of the 8 or more species of malaria-bearing *Anopheles*, and *Stegomyia fasciata* (formerly known as *Culex fasciatus*), the carrier of yellow fever.

Mosquitoes and Malaria.—The indigenous malarial species are as follows:

1. *Anopheles maculipennis* (*A. quadrimaculatus, A. claviger*) (Figs.

FIG. 100.

Anopheles maculipennis. Male.

FIG. 101.

Anopheles maculipennis. Female.

100 and 101) has the "dappled wings" described by Ross. The palpi are black.

2. *Anopheles punctipennis* has a yellowish-white spot extending about three-fourths of the length of the front margin of the wing. (Figs. 102 and 103.)

3. *Anopheles crucians.*—The scales of the last wing-vein are white, marked with three black spots. The palpi are marked with white at the bases of the last four joints. (Figs. 104 and 105.)

A. maculipennis and *A. punctipennis* are distributed very widely,

[1] Mosquitoes, New York, 1901, p. 230.

being found in greater or lesser abundance throughout the country. The former is the most common *Anopheles* in the malarial districts of Africa and Southern Europe, and is found in Great Britain, Germany, France, and elsewhere.

FIG. 102.

Anopheles punctipennis. Male. (After Howard.)

A. crucians is a Southern form, believed to be the carrier of the pernicious, tropical, æstivo-autumnal fever, but not the only one, for in St. Lucia, for example, where the great majority of cases of malaria are of the pernicious type, the common mosquito is *A. albipes.*

FIG. 103.

Anopheles punctipennis. Female. (After Howard.)

Unlike *Culices* and *Stegomyia*, the *Anopheles* do not breed in rain-water barrels, troughs, cisterns, tin cans, pitcher plants, and other small receptacles, but in pools, puddles, ditches, canals, and other bodies of stagnant or but very slowly moving water. The larvæ thrive

in clean or foul water, but not in that which is so foul as to stink; they cannot live in salt- or very brackish water, nor where there is rapid movement.

Fig. 104.

Anopheles crucians. Male.

It is only the female imago that sucks human blood, and she is active only at night. She enters dwellings about sundown or later,

Fig. 105.

Anopheles crucians. Female.

and, unless leaving before morning, seeks out the darkest corner in which to pass the day.

According to Nuttall,[1] *Anopheles* are attracted variously by different

[1] British Medical Journal, September 14, 1901, p. 668.

colors, navy blue being the most attractive, followed by dark red, reddish brown, scarlet, black, and slate gray. Yellow, orange, white, and ochre proved to attract the least. Joly is quoted as stating that mosquitoes in Madagascar are attracted more to brown than to red soil or white sand; that wearers of black shoes and stockings are bitten more than those who wear white; that blacks are bitten more than whites, and black dogs than yellow. Nuttall noted in his experiments that, while the imagines frequently flew up and settled on persons entering the room clad in dark clothes, they never did when the dress was white. He suggests the employment of boxes colored dark inside, in which the pests may be caught and destroyed. The influence of color is noted also by Osborne Brown,[1] who holds that walls, furniture, etc., should be of light color, and advises, among other measures, the putting away of all dark clothes. *Anopheles* appear to be attracted also by odors, according to the testimony of Stephens and Christophers,[2] who found that when native Africans slept in a tent previously occupied by Europeans, the insects congregated there more numerously. During European occupancy, 2 *Anopheles* were usually found in the morning; but after the first night of African occupancy, 19 were caught, and after the second night, no less than 62 were found.

The Malarial Parasite.—The malarial parasite was discovered in 1880, by Laveran, a French military surgeon stationed in Algeria, but until some years later its method of development was not demonstrated, and only recently has anything been known definitely as to the manner of its entrance into the human body. Before proceeding to an account of the researches by which this was determined, it may be well to describe the development of the parasite within the human subject and within the mosquito.

The several malarial parasites belong to the lowest order of the animal kingdom, the protozoa, suborder *Hœmosporidia*. The different forms corresponding to the clinical varieties of the disease were differentiated in 1886 by Golgi, one of the most prominent of the Italian biologists, who, between 1885 and 1890, were the first to pay especial attention to Laveran's discovery, and study the life cycle of the parasite in the red blood-corpuscle. In this it appears as an amœbula, which grows, digesting the red coloring matter, until it occupies nearly the whole volume of the corpuscle and shows spots of pigment in its interior. Then the nucleus divides and forms spores, which, when the cell wall bursts, are liberated into the blood plasma. This point marks the beginning of the malarial chill. The spores enter into other corpuscles, develop into mature organisms, segment, and produce new spores, which on being liberated proceed to infect other corpuscles, and so the process continues. In the tertian form of fever, this process of sporulation occurs at intervals of forty-eight hours; in the quartan form, which is comparatively rare, the intervals are seventy-two hours; in the pernicious æstivo-autumnal form, the intervals are very irregu-

[1] Journal of Tropical Medicine, October 1, 1901.
[2] Quoted by Nuttall, Journal of Hygiene, January, 1901, p. 7.

lar, and the successive processes of sporulation may occur so rapidly that the fever becomes continuous.

After a number of generations of these asexual forms, male and female parasites appear, which are incapable of further reproduction within the human subject, but require external conditions which they find within the body of *Anopheles* mosquitoes. The female parasites are known as *macrogametes*, homologous with ova; the male organisms are known as *microgametocytes*. They give off flagella or *microgametes*, homologous with spermatozoa. In the next cycle, discovered by Ross, these adult sexual forms, when sucked up in the blood by the mosquito, coalesce in its stomach. The fertilized organisms attach themselves to the walls and penetrate to the outer muscular wall, where they increase in size and become mature zygotes (*sporocysts*), upon the surface of which, clear spaces, *centromeres*, begin to appear. In a short time, these become surrounded by minute spindle-shaped cells, *sporoblasts*, which divide into minute rods, *sporozoites*, which soon fill the whole cyst, which bursts and liberates them through the outer wall into the abdominal cavity. They then rapidly penetrate the tissues to the salivary duct, and thence into the proboscis, from which they are discharged with the salivary secretion into the blood of the next person bitten. From the time of entrance of the sexual forms into the mosquito to the completion of the process, about ten days elapse, and since the period of incubation in man is the same, it follows that, under favoring conditions of temperature (for in cool weather the process within the mosquito is slower), about twenty days must elapse between the appearance of a first case and that of another connected therewith. The inoculated sporozoites give rise to the successive asexual generations above described.

The tertian parasite invades the whole corpuscle; the quartan, nearly the whole; the æstivo-autumnal, from a fifth to a fourth of its volume. The pigment granules in the tertian form are fine; in the quartan, coarse; in the æstivo-autumnal, very fine.

Not alone man, but many of the lower animals, as cattle, sheep, monkeys, dogs, various species of birds, frogs, snakes, turtles, lizards, etc., are subject to malaria; but the parasites are peculiar to each species, and are not transferable from one to another.

Some years after Golgi and others of the Italian school had differentiated the several malarial parasites and traced their life cycle within the human subject, Manson, who had done much work in the investigation of mosquitoes as a causative agent of filariasis, announced, in 1894, his belief that malaria was caused by drinking water infected by mosquitoes or dust from the dried mud left on evaporation of the water in which they had bred. He believed that the female, already infested with the protozoon, laid her eggs and then died in the water, and was later devoured by the larvæ. Bignami opposed this, and asserted that the infection was conveyed directly by inoculation in the process of sucking blood.

In 1895, Ross discovered the malarial crescents in the stomachs of

mosquitoes that had bitten a malarial subject, and followed them in their development into spheres and flagellated bodies, but was unable to find them in the body cavity or observe any metamorphosis there. For two years, Ross[1] endeavored to cultivate the parasite in mosquitoes, but without success, and he then ceased experimenting with the "brown and gray" species (*Culex*), and began anew with a few specimens of a larger kind having four black spots on the wings (*Anopheles*). After these had fed on malarial blood, he observed, on examination of one of them, certain pigmented cells, "the pigment absolutely identical in appearance with the well-known characteristic pigment of the malarial parasite." In a second mosquito, killed a day later, the cells were observed to be larger. The supply of *Anopheles* having become exhausted, he worked with other kinds, but with no results; but later[2] he announced that he had found the pigmented cells in a third "dapple-winged" mosquito fed on crescent-containing blood. In the meantime, MacCallum, of Johns Hopkins,[3] announced his discovery that with *halteridum*, a parasite of birds strictly analogous to the malarial parasite of man, the function of the flagellum is that of true spermatozoa. Ross then took up the study of bird parasites (*Halteridium* and *Proteosoma*), especially of the proteosoma of sparrows, larks, and crows, and was successful in growing the parasites in mosquitoes that had bitten sick sparrows, and in reproducing the disease in other birds bitten by them. He observed the liberation of the sporozoites from the zygotes, their passage into the body cavity of the insects, and their presence in the salivary glands. His belief that *Anopheles* acts as a carrier of the malarial parasites was proved by Grassi, Bastianelli, and Bignami, who allowed different kinds of mosquitoes, including *A. maculipennis*, to bite persons afflicted with the æstivo-autumnal type of fever, and found only in the species mentioned the developmental changes described by him. Later, Bignami[4] reported that he, Grassi, and Bastianelli had caught a number of specimens of this mosquito in a malarious district twenty-two miles from Rome, and had released them at the Santo Spirito Hospital in a room occupied for some years by a man who had been under constant observation and had had no kind of fever whatever. The experiment yielded positive results, for the volunteer subject acquired the fever and yielded parasites in his blood. The demonstration of the agency of these pests was thus complete, and the connection has been proved repeatedly on a much larger scale. Thus, Ross[5] reports that of 21 persons in a camp near Calcutta, 17 who slept without the protection of mosquito-netting were seized with malaria, while the others who slept under nets escaped. Grassi's experience is equally convincing, although without a control. For eight consecutive days, accompanied by a family of seven, he left Rome each day at 5.30 in the afternoon and went to a

[1] British Medical Journal, December 18, 1897, p. 1786.
[2] Ibidem, February 26, 1898, p. 550.
[3] Journal of Experimental Medicine, January 7, 1898.
[4] Bulletino della R. Accad. Med. di Roma, XXV., 1898–1899.
[5] British Medical Journal, July 22, 1899.

cottage in a notoriously malarious district between Rome and Civitavecchia, where they passed the nights in a cottage, the windows of which, screened with perforated zinc, were left open all the time. Not one of the party was in the least affected.

The longer experiment of Sambon and Low in an equally malarious district is even more convincing. They spent several months, including the summer of 1900, with malaria raging all about them, but were themselves not affected. They took no drugs by way of prophylaxis, and went about freely by day, but kept indoors between sunset and sunrise, protected by nettings and screens.

In 1901, an interesting experiment was tried by the Japanese government with two battalions of soldiers stationed together in Formosa. One battalion was completely protected from mosquitoes for 161 days during the malarial season, and not a man had the disease. In the other battalion, which was not protected, 259 cases were observed.

Another interesting experiment was that conducted by Fermi and Cano-Brusco,[1] who took 16 persons, ranging from eighteen to thirty years of age, who had had no malaria within a year, to a malarious place in Sardinia and kept them there eight days. Half were protected from mosquitoes at night, and the others not. Of the non-protected, 5 were seized; of the 8 protected, not one.

The most convincing proof of the agency of mosquitoes may be said to be the occurrence of the disease in a non-malarious country through inoculation by mosquitoes imported from another where malaria abounds. Such an instance is reported by Manson,[2] whose son was bitten in London on three different days by infected mosquitoes brought from Italy. Within a few days of the third inoculation, the characteristic symptoms of tertian malarial fever appeared and the parasites were found in the blood.

For the spread of malaria, two factors are thus evidently essential: the parasite in human blood and the *Anopheles* mosquito. Either alone is impotent. There are many places where *Anopheles* are common and malaria unknown. Indeed, if the *Anopheles* alone could cause the disease, no place would be safe, for although they are not strong fliers, they may be transported through hundreds and even thousands of miles by the vehicles of ordinary travel. Thus Grassi relates that, during a drive lasting two hours, he caught 200 specimens inside the coach; and others have noted their presence in railroad cars and passenger ships. Whether they would be able to breed aboard ship is doubtful, although instances of breeding of other mosquitoes in this manner are known. Thus, Dr. Cumming, of the Marine-Hospital Service, reported on August 2, 1901, to the Supervising Surgeon-General, the case of the Spanish barque *Maria Blanquer*, which was free from mosquitoes until the twenty-second day out from Rio de Janeiro, when some were noticed in the water tank when it was opened, after which the crew were attacked so persistently by

[1] Centralblatt für Bakteriologie, etc., XXIX., p. 985.
[2] British Medical Journal, September 29, 1900.

them that they were obliged to cover themselves to get any sleep. After fumigation of the forecastle, the dead mosquitoes could be scooped up in the hand. Howard relates that mosquitoes were introduced into the Hawaiian Islands by sailing vessels from the United States, and deems it probable that they bred more or less continuously in the water barrels during the voyage.

Mosquitoes may be blown along by the wind through long distances, but ordinarily they take shelter on the leeward side of any object as soon as the wind begins to be strong. Howard cites an instance of mosquitoes crossing a strip of water a mile wide, aided by gentle and continuous wind, and another in which a migratory cloud of the insects, extending three miles in width, traversed 60 miles; and Dr. Kallock, of the Gulf Quarantine Station, reports (August 2, 1901) that the captain of the ship *America* stated that mosquitoes came aboard the vessel when she was at least 10 miles from land. But *Anopheles* are not likely to fly far from their birthplaces. They are not such strong fliers as *Culices*. Stephens and Christophers[1] believe that *Anopheles* in Sierra Leone may fly a quarter of a mile or farther, but in Freetown they found them scarce at a distance of 200 yards from their breeding-places.

As stated above, there are many places in this country and elsewhere where *Anopheles* are common and malaria unknown, although formerly the disease may have raged most extensively. In England, for example, where malaria was once one of the great national scourges and is now seen only rarely, Nuttall[2] and his associates found, in 1900, specimens either of the imago or of the larvæ in no less than 173 different places. In some of these places, malaria, so far as known, has never existed; in others, it once had raged extensively. In France, Sergent[3] has found *A. maculipennis* and *A. bifurcatus* in great abundance where malaria was formerly common, but now is, and for twenty years has been, unknown; and in Germany, Pfeiffer[4] has found them in great numbers in formerly malarious districts, but none of them showed the presence of the parasite. In Italy, too, where Grassi has held that the geographical distribution of *Anopheles* is identical with that of malaria, Celli[5] has found the insects in situations where malaria has never been known.

To what the disappearance of malaria in England, Scotland, parts of the United States, France, Germany, and other countries, is due, is not easily explained. To a very large extent, it is doubtless due to drainage of the land and general sanitary improvement, the drying of the soil diminishing the opportunity for puddle-breeding mosquitoes to multiply. But this explanation will not apply generally, for in many places now free from malaria the same conditions of soil, wetness, and mosquitoes are found to-day as existed when the disease was endemic. It is interesting to note that, in England, the *Anopheles*, although fairly

[1] Loco citato.
[2] Journal of Hygiene, January, 1901, p. 4.
[3] Annales de l'Institut Pasteur, XV., Oct. 25, 1901.
[4] Correspondenzblatt des allgemeinen ärztlichen Vereins von Thüringen, 1901, No. 7.
[5] Centralblatt für Bakteriologie, etc., XXVIII., p. 534.

common, does not bite; at least Nuttall states that neither he nor any of his associates was bitten while collecting, and that Mr. Theobald, of the British Museum, wrote that he had never known them to bite in England. (It is to be remembered that mosquitoes are naturally vegetarians.)

Nuttall suggests as a second reason for the disappearance of malaria from England the reduction of the population of the infected districts by emigration at about the time of the disappearance. This would, of course, reduce the number of infected individuals and lessen the chance of the *Anopheles* becoming infected. Koch and many others are strongly of the opinion that the use of quinine has had more to do with the disappearance of malaria than anything else, but it is probable that there is some other as yet unrecognized cause, and that all the influences mentioned have contributed in different degrees. That there is some such undiscovered local condition, must be very evident when we consider the following facts published by Celli and Gasperini:[1] Certain localities in Tuscany, which less than thirty years ago were very malarious, are to-day, so far as can be ascertained, in precisely the same general condition as obtained before malaria disappeared therefrom. The stagnant marsh-water swarms with *Anopheles* larvæ, and the air above with myriads of the imagines. There is no lack of the malarial parasite for infection of the mosquitoes, for the people go to other districts and return with malaria; and yet, in spite of the presence of the essential factors for an extensive epidemic, no outbreak occurs. The children are robust and healthy, the adult population shows no effects of malaria, and many who have lived there all their lives have never had the slightest attack of the fever. This freedom is not due to acquired immunity, for the inhabitants take the disease when they go to malarious districts for work. The mosquitoes are not insusceptible to infection, for specimens captured there are readily infected by malarial blood in Rome. Quinine cannot be credited with being the cause of the exemption, for it is not used more extensively than elsewhere. In India, too, there are districts which were formerly malarious, but are now comparatively healthy in spite of apparently unchanged conditions.

But although *Anopheles* may exist where malaria is unknown, the converse is not true, for where malaria is, there, also, are mosquitoes. The assertion that in Java there are places where malaria abounds without mosquitoes, has been investigated by Koch, who found that mosquitoes were everywhere present where malaria prevailed. He found also a place in East Africa with all the conditions favorable to malaria excepting mosquitoes, but with no evidence of the disease. In many of the islands of Polynesia, where marshes are very extensive and all malarial conditions are present at their maximum, with the exception of mosquitoes, no malaria is known.

It seems reasonable to assume that, given the necessary species of mosquitoes, the introduction of infected persons into a district would probably be followed by the appearance of other cases; but there are,

[1] Centralblatt für Bakteriologie, etc., Oct. 23, 1901, p. 523.

fortunately, a number of conditions which must be fulfilled in order to bring this about. First, the *Anopheles* must be blood-drinkers; second, they must bite the infected individuals; third, they must then develop the parasite within themselves; and, fourth, they must live to bite another person when the sporozoites are still present in the salivary duct. In addition, certain favoring conditions of temperature are required, both for the activity of the mosquito and for the development of the parasite. Should cold weather come on shortly after the malarial subject is bitten, no harm might follow, for about ten days are required before the mosquito becomes fully infective, and in a cold atmosphere she is sluggish and will not bite.

Preventive Measures.—In order to prevent multiplication of *Anopheles*, measures should be taken to diminish the number of breeding-places by drainage and other means, and the larvæ should be destroyed where it is not possible to accomplish removal of the water. The natural enemies of the larvæ may be introduced at very slight expense and with a minimum of trouble. Among these, Howard mentions as most efficacious, sunfish, sticklebacks, and top-minnows. Where fish cannot be introduced, the application of the cheapest kerosene at regular intervals will not only kill all larvæ, but will prevent the impregnated female from laying her eggs. Kerosene spreads easily and does not evaporate too quickly, and a barrel will suffice for an area larger than two acres. A single application by means of mops or watering-pots—about an ounce to fifteen square feet, enough to give a very thin film—will remain for at least a week, and generally a fortnight; and since a week must elapse for eggs to develop into pupæ, a second application need not be made until about seventeen days have elapsed.

The sick should be protected by mosquito-netting, and the same means should be employed to prevent access to the houses of the well, and for the protection of those who may be obliged to sleep in the open. Local applications to the skin (oil of pennyroyal, oil of eucalyptus, etc.) are not of much value.

Fermi and Tonsini[1] have reported a noteworthy instance of diminution in the amount of malaria after systematic destruction of the larvæ of mosquitoes. The Island of Asinara, inhabited solely by convicts and their guards, has often been ravaged by malaria. The larvæ of different species of mosquitoes were found in many wells and horse-ponds, and were treated with kerosene a number of times. Screens were placed in the windows and doors of the dormitories. The results were most satisfactory, only 9 cases of malaria occurring during the year, against 99 in the year preceding.

If *Anopheles* gain access to houses, they may be destroyed by fumigation with sulphur dioxide, employing 1 pound of sulphur for each 1000 cubic feet of air space.

For prophylaxis by means of quinine sulphate, the daily ingestion of 2.5 to 5 grains is advised. However efficacious this may be, it will have to be admitted that it is an expensive measure, for the mini-

[1] Zeitschrift für Hygiene und Infectionskrankheiten, XXX., p. 534.

mum dose advised would require the annual use of no less than 65 tons per million population.

Mosquitoes and Yellow Fever.—Since 1693, when yellow fever made its first appearance in this country, there have been no less than 95 epidemics of greater or lesser magnitude within the United States. According to Reed and Carroll,[1] since 1793 the disease has been the cause of no less than 100,000 deaths, 41,348 of which have occurred in New Orleans, 10,038 in Philadelphia, and 7759 in Memphis (1855, '73, '78, '79). Between 1851 and 1883, it caused 23,338 deaths at Rio de Janeiro, where, according to Gouvéa,[2] previous to 1849 it was unknown, being introduced in that year by the *Brazil* from New Orleans and Havana, and by the *Navarre* from Bahia. From Rio it spread to all the towns in the bay. Between 1853 and 1900, it caused 35,952 deaths at Havana, where it had flourished continuously for more than a century, and where, after a practical application of the knowledge concerning the method of its dissemination—the outcome of brilliant work on the part of Reed and his associates, of the United States Army—it was demonstrated that it could be completely eradicated, and that even though outbreaks should occur on ships arriving from infected ports, removal of the victims to the fever hospital need give rise to no new cases.

Inability to control the spread of the disease has hitherto been due to the fact that the manner of its dissemination was not known, and that all efforts to control it were exerted in the wrong direction, in the belief, now shown to have been unfounded, that fomites, filth, and soil conditions were the distributing agencies.

It was in 1848 that Dr. Josiah Nott, of Mobile, suggested that mosquitoes might be responsible for or connected with the spread of yellow fever, but the idea appears to have been received with indifference. In 1881, Dr. Finlay, of Havana, announced his theory of mosquito transference, and began his experiments, but it remained for Reed and his associates to demonstrate conclusively that mosquitoes are the principal, if not the sole, carriers of the exciting cause, and that fomites and filth have absolutely no influence whatever.

The experiments proving both statements are exceedingly interesting. In October, 1900, Reed[3] reported positive results of experiments conducted by himself and Drs. Carroll, Agramonte, and Lazear with mosquitoes, *Stegomyia fasciata*, furnished by Dr. Finlay. Carroll was bitten by one that had bitten four yellow fever patients, alternately severe and mild cases, respectively, twelve, six, four, and two days previously. Four days afterward he took to his bed, and on the fifth day his disease was diagnosed as yellow fever. Another subject was bitten by the same mosquito, and by three others that had previously bitten patients with the disease, and in seven days he also had the fever. Dr. Lazear was bitten without result by an infected mosquito

[1] Medical Record, October 26, 1901, p. 641.
[2] Bulletin médical, October 12, 1901, p. 861.
[3] Philadelphia Medical Journal, October 27, 1900.

on August 16th, and by another, an accidental stranger, on September 13th. In five days, he had a chill; on the day following, the diagnosis of yellow fever was made, and in a week, the case terminated fatally. Between August 17th and October 13th (fifty-seven days), these three were the only cases which occurred among 1400 non-immune Americans at Quemados.

On November 20, 1900, an experiment station, Camp Lazear, was established at Columbia Barracks, Cuba, under the direction of Reed, who, with his former associates, continued the work with gratifying results. A very strict quarantine was established, and no non-immune was subjected to mosquito inoculation (with one exception) who had not passed the full period of incubation of yellow fever under close observation, nor was any non-immune who left the camp permitted to return under any circumstances. Twenty-one subjects presented themselves, mostly immigrant Spaniards seeking immunity, and the result in each case was positive.

Experiments with fomites[1] were equally convincing in results. Three large boxes of sheets, pillow-slips, blankets, etc., contaminated with the discharges of yellow fever patients, many of them purposely soiled with black vomit, urine, and fæces, were placed in a building of 2800 cubic feet capacity, tightly ceiled and battened, with small windows to prevent thorough circulation of air and wooden shutters to prevent the disinfectant action of sunlight. The windows were screened with wire gauze, and the entrance with a screen door. The articles were unpacked by Dr. Cooke and two privates, and they were shaken so that the specific agent might be disseminated throughout the room, if it were present. They were then used on the three beds provided, and some were hung about the room and near the beds. For twenty consecutive nights, the three slept in the uninviting beds, and every morning they packed the filthy articles back into the boxes, and every evening unpacked and distributed them again. They passed their days in tents in quarantine. During their tour of service, other bedding, soiled with the bloody stools of a fatal case, was received in a most offensive stinking condition, and used with the rest. Then other non-immunes repeated the experiment for twenty-one nights, sleeping in the very garments which had been used by patients. Then these subjects were followed by others, who, for fourteen nights out of twenty, slept with pillows covered with towels that had been thoroughly soiled with blood drawn from a case of well-marked yellow fever on the first day of the disease. The result of the exposure of these non-immunes in relays for nine weeks was wholly negative, for not one had the first symptom of yellow fever. Not so, however, in the case of a man who was exposed in a building of similar size, thoroughly ventilated, and containing only disinfected articles plus infected mosquitoes. On December 15, 1900, 15 of the insects were set free, and he was soon bitten several times. Later, he was bitten again, and also on the following day. He contracted the disease; but 2 men who

[1] Reported in Medical Record, October 26, 1901, and in other American journals.

slept for eighteen nights in a half of the room which was screened from the other and from the mosquitoes by netting, had no symptoms.

Whatever the nature of the parasite, its life cycle would appear not to need the passage of the parasite through the intermediate host, for Reed[1] and his associates succeeded in producing the disease by injection of blood drawn from the general circulation. Although the specific *causa morbi* has not yet been discovered, it appears to be definitely settled that it is not Sanarelli's *B. icteroides*.

The conclusions arrived at by Reed, Carroll, and Agramonte, and reported to the American Medical Association, are, in brief, as follows: The intermediate host is the *Stegomyia fasciata*, which is capable of transmitting the disease after an interval of about twelve days or longer after becoming contaminated by biting a person already sick. The disease can be caused by subcutaneous injection of blood from the general circulation during the first or second day of sickness. Immunity is not conferred by the bite of a mosquito at an earlier period after contamination; but when the disease is produced through the agency of a mosquito, the subject is immune against infection by subcutaneous injection of blood. The period of incubation in cases of induced fever varied from forty-one hours to five days and seventeen hours. The disease is not conveyed by fomites, and hence disinfection of a house, except as to mosquitoes, is unnecessary. The spread of the disease can be controlled most effectually by measures directed to the destruction of mosquitoes and to protection of the sick against them.

That not less than twelve days are required for the contaminated mosquito to acquire the power to transmit the disease, is borne out by the observations of Dr. H. R. Carter,[2] who found that, in sixteen houses in which 95 secondary cases of yellow fever occurred, the interval between the first and second cases ranged between twelve and twenty-three days.

The Yellow Fever Mosquito, *Stegomyia fasciata* (Figs. 106 and 107), formerly known as *Culex fasciatus*, is, in this country, confined principally to the tropical and subtropical regions along the Atlantic Ocean and Gulf of Mexico, but may be transferred from one region to another by the usual vehicles of travel. It is found in all the principal cities and some of the smaller towns of Cuba; in Jamaica, Isle of Pines, and Nicaragua; in Louisiana, especially in New Orleans; in Eastern Texas; in various places in other Southern States; in a number of towns and cities in Brazil, and in certain other hot countries. It is not essentially an American species, for Mr. Theobald, of the British Museum, states that he has received specimens from Italy, Greece, Spain, Portugal, and Malta. Its presence in Spain may explain the occurrence, in 1800, of a very extensive epidemic of yellow fever in the province of Andalusia, and, in 1821, of another at Barcelona. Wherever it is found, it appears to prefer the larger, populous centres, and to be but little common in rural districts.

[1] Philadelphia Medical Journal, July 6, 1901.
[2] Medical Record, June 15, 1901, p. 933.

The *Stegomyia* breeds, like *Culices*, in small collections of water. Reed and Carroll found the larvæ in rain-water barrels, sagging gutters containing rain-water, cesspools, tin cans used for removing excreta, tin cans placed about table legs to prevent inroads of red ants, horse-troughs, leaves of the *Agave Americana*, and generally in any collection of still water. The New Orleans Mosquito Commission[1] found the larvæ in 128 of 210 cisterns examined by them. According to this authority, the life cycle of *Stegomyia* is somewhat different from that of other genera, and these differences may necessitate more stringent measures than will suffice for the suppression of *Culices* and *Anopheles*, for the eggs hatch earlier (ten to twenty-four hours), and the larval (six and one-half to eight days) and pupal stages (two days) are much shorter, so that full development requires from two to four days less than for *Culex pungens*, and two weeks less than for any species of *Anopheles*. According to Reed and Carroll, the eggs begin

Fig. 106.

Stegomyia fasciata. Male. (After Howard.)

Fig. 107.

Stegomyia fasciata. Female. (After Howard.)

to hatch, as a rule, on the third day, and the process may last about a week; the larval stage lasts seven or eight days and the pupal stage two days; the shortest time for complete development observed by them was nine and one-half days. At an average temperature of 75° F. or higher, the species multiplies abundantly, but exposure to a lower temperature for even a short time daily causes much retardation, and eggs kept at 68° F. do not hatch. They found that newly hatched larvæ kept at 68° F. develop slowly, and require twenty days to reach the pupal stage; kept at 50° F., they fail to reach the pupal stage.

Although low temperatures are destructive of the larvæ, it is otherwise with the eggs, which Reed and Carroll found to be very resistant to the influence of dryness and cold. They observed that eggs which had been dried on filter-paper and kept ninety days hatched promptly

[1] New Orleans Medical and Surgical Journal, January, 1902.

on being placed in water. Dried eggs, brought from Havana to Washington in February, were easily hatched in May, and furnished about 60 per cent. of the usual number of larvæ hatched from fresh eggs. Eggs frozen for an hour, thawed out at room temperature, and placed in an incubator at 95° F., began to hatch on the sixth day, and furnished active larvæ on the eighth; while others, frozen for a half hour on two successive days, began to hatch under the same conditions on the third day. Thus it would appear that eggs may survive the Havana winter, and that the presence of hibernating females is not necessary.

The female imago, when impregnated, is generally ready to bite on the second or third day. In New Orleans, according to the Mosquito Commission, the mosquitoes are active during the day, and particularly in the afternoon. In Cuba, Reed and Carroll found them to be especially active from 4 P. M. until midnight, although in captivity the hungry impregnated female will bite at any hour. When freed in a room, she does not appear to bite a second time within five to seven days.

Having bitten a yellow fever patient, it appears that the mosquito is incapable of inducing the disease before twelve days have passed. Those which failed to infect on the eleventh day were successful on the seventeenth. How long the ability to infect continues, was not determined, but successful inoculation was brought about as late as fifty-seven days after contamination.

How long the infected mosquito will live, is not known. The specimen which conveyed the disease on the fifty-seventh day lived seventy-one days, others have been known to live five months, but the majority die in captivity within five weeks. In a state of freedom their length of life depends largely upon access to water.

At temperatures below 62° F., *Stegomyia* will not bite, and thus Reed accounts for the decline in epidemics of yellow fever at New Orleans in November, when the mean temperature is 61.8° F., and their cessation in December, when it falls to 55.3°.

Preventive Measures.—To avoid epidemics of yellow fever, Reed advocates the prevention of importation of cases of the disease from infected localities, and, when cases do appear, the application of measures to protect the sick from attacks of mosquitoes. Screens should be used for this purpose, and even the dead should be thus protected, for *Stegomyia* will bite even these. All mosquitoes in a house where a case occurs should be caught, and search should be made for them in all the houses in the immediate vicinity. They may be destroyed by fumigation with sulphur dioxide (1 pound of sulphur for each 1000 cubic feet of air-space), which Rosenau[1] finds far superior for this purpose to formaldehyde, for very small amounts of the dry gas will kill them, even when they are protected by four layers of towelling, while formaldehyde acts feebly and with uncertainty. Pyrethrum (Dalmatian) powder may be burned in the same proportion, and will either kill or stupefy them, so that in three hours they may be swept up and burned.

[1] Bulletin No. 6, Hygiene Laboratory of the U. S. M.-H. S., September, 1901.

Non-immunes entering infected houses are advised to rub all exposed surfaces, including the ankles, with spirits of camphor, oil of pennyroyal, or 5 per cent. menthol ointment; but these agents exert only a temporary protective influence against being bitten.

Of very great importance is the destruction of larvæ and of breeding-places. The results of systematic work in this direction and of other preventive measures are manifest in the immense improvement in the sanitary condition of Havana. Under the direction of Dr. W. C. Gorgas, U. S. A.,[1] the "Stegomyia Brigade" began its work of inspection in March, 1901, when, in 16,000 houses examined, larvæ were found "at the rate of 100 per cent. This does not mean that every house examined had larvæ; many houses were found that had several receptacles which contained larvæ." During December, 1901, 16,121 houses were inspected, and in but 1.5 per cent. were the larvæ found. From May 7 to July 1 (fifty-four days), no case of the disease occured; then it was introduced from Santiago de las Vegas, and later from other places, and yet, during July, there were but 4 cases, and in August, but 8. During the whole year (1901), there were but 18 deaths from yellow fever, and 12 of these occurred in January and February, before the work of prevention was begun. During the preceding forty-five years, the average number of deaths therefrom was 751.44, the minimum, 51, occurring in 1866.

Mosquitoes and Filarial Disease.—In 1872, Dr. Timothy Lewis, of Calcutta, discovered that human blood is the normal habitat of the embryo nematode discovered, in 1863, by Demarquay, in the milky fluid from chylous dropsy of the tunica vaginalis, and named it *Filaria sanguinis hominis*. Later, Manson, in consequence of the discovery of other filariæ in the blood, renamed this parasite *Filaria nocturna*, and named the others *F. diurna*, *F. perstans*, *F. Demarquaii*, and *F. Ozzardi*. The most important of these is *F. Nocturna*, which is the embryo of *F. Bancrofti*, discovered in 1876 by Bancroft, of Australia, in patients with lymph-scrotum, and named in his honor by Cobbold. The parental form is a hair-like nematode, from 3 to 4 inches long, which infests small cyst-like dilatations of the distal lymphatics, lymphatic varices, the larger lymphatic trunks between the glands, the lymphatic glands, and the thoracic duct. The embryos, which are about an eightieth of an inch in length, and about as broad as the diameter of a red blood-corpuscle, are found in the blood of persons afflicted with filariasis from just before the approach of night until about 8, or 9, or 10 o'clock in the morning. They enter the general circulation as night approaches, and increase gradually in number until about midnight, after which they gradually decrease until the time above mentioned, when they disappear from the peripheral circulation. According to Manson, it is not unusual to find at midnight as many as 300 to 600 in a single drop of blood, from which he concludes that, at that hour, as many as 40 or 50 millions of them may be circulating simultaneously

[1] Public Health Reports, February 14, 1902, p. 363.

in the blood-vessels. During the day, they may be found in the larger arteries and in the lungs.

The parasite is found indigenous in almost all tropical and subtropical countries, and in this country as far north as Charleston, S. C. In many places, a half, and even more, of the population are found to be infested.

According to Manson, the following diseases are known to be produced by this parasite: abscess; lymphangitis; varicose groin and axillary glands; lymph-scrotum; cutaneous and deep lymphatic varix; orchitis; chyluria; elephantiasis of the leg, scrotum, vulva, arm, mammæ, and elsewhere; chylous dropsy of the tunica vaginalis; chylous ascites; chylous diarrhœa; and probably other diseases due to obstruction or varicosity of the lymphatics or to the death of the parent worm.

In 1878, Manson, having conceived the idea that mosquitoes might be instrumental in spreading the disease by acting as an intermediate host, observed the development of filariæ in a species of *Culex* (*C. ciliaris, vel pipiens*), which was allowed to bite an infected person. Within a few hours, the blood plasma in the mosquito's stomach becomes thickened, but not coagulated, and some of the embryos manage to escape from their sheaths and then move freely in the blood, and finally escape from the stomach and enter the thoracic muscles, where they remain a number of days and undergo a process of metamorphosis, which results in the formation of a mouth, an alimentary canal, a peculiar trilobed tail, and great increase in size.

It was Manson's idea that the infested mosquito repaired to some body of water, laid her eggs, and died; and that the parasites freed themselves from the dead body, lived in the water, and, being received into the stomach of man through drinking, bored their way through the tissues and entered the lymphatic trunks, where, attaining sexual maturity, fecundation occurred, resulting in due course of time in new generations of embryos to be poured into the lymph, then through the glands or by the lymphatics into the general circulation. Bancroft, however, suggested that the parasite is transmitted back to man not through drinking-water, but by the bite of the mosquito; and in 1900, G. C. Low discovered that the metamorphosed worm makes its way to the insect's head, and finally into the root of the proboscis, in which it lies until the mosquito bites another person, when, stimulated into activity by the warmth of the encompassing tissues, it moves from its position in the proboscis and enters the wound. The worms thus introduced undergo farther development in their new position in the skin and become adults, and proceed to breed embryos, which enter the lymph spaces or vessels.

According to Manson, in most cases of infection the parasite exercises no manifest injurious influence whatever, and in those cases in which injury is caused, the trouble is due in the main to obstruction of the lymphatics by the parent worms.

At first it was believed that the intermediate host was *Culex ciliaris* (*vel pipiens*) alone, but a number of other mosquitoes are now known to act, including species of *Culex* and *Anopheles*. These include, according to James, *A. Rossii*, *C. albopunctatus*, and *C. microannulatus*; and, according to Low,[1] *C. fatigans*; and to Vincent,[2] *A. albimanus*. Low reports that, in Barbadoes, neither malaria nor any species of *Anopheles* is known, but that there are much filarial disease and an extraordinary abundance of *C. fatigans*. In 600 blood examinations of persons taken at random, 12.66 per cent. yielded *Filaria nocturna*. In Trinidad, Vincent found in 500 cases taken at random, 5 per cent. infested with filariæ and 6.6 per cent. with elephantoid disease. In *Culex fatigans*, it was observed that the final stage of metamorphosis was reached between the sixteenth and nineteenth days, but with *A. albimanus*, since none of the specimens lived in captivity beyond the twelfth day, it was not possible to determine definitely when the final stage is reached. In the case of *C. ciliaris*, Bancroft prolonged the life of the insect and followed the development of the parasite to the last stage of its metamorphosis, which occurred, under favorable conditions of temperature, at about the sixteenth or seventeenth day after feeding.

Filaria diurna is a form which is detected in the blood only by day, and it has been supposed to be a distinct species, although nothing is known about its life history or pathological significance. According to the findings of the Nigeria Malaria Expedition,[3] however, there are so many points of resemblance between the two forms that it is possible that they may be identical. It is pointed out that the geographical distribution of the two forms is in close agreement, although in many places where *F. nocturna* is known to exist, *F. diurna* has not been noted; but the latter is not known to exist where the former is absent. Furthermore, in some of the Pacific islands where elephantiasis is exceedingly common and *F. nocturna* is found, there is none of the characteristic nocturnal periodicity. Where both were found, the members of the expedition were unable to distinguish in any way the one form from the other. In some cases, embryos were found during both day and night. It is known that when persons infested with *F. nocturna* change ther habits, so that they sleep by day and keep about by night, the filariæ are found in the peripheral circulation only during the day.

Filaria Demarquaii resembles *F. diurna* and *F. nocturna* in shape, but not in size, being about half as large. It is present in the blood both by day and by night in the peripheral circulation. Low[4] has attempted, without success, to determine the intermediate host necessary for the development of the embryos to the point where they are capable of farther growth in man, but is of the opinion that the intermediate host is a blood-sucking insect.

Mosquitoes and Dengue.—Concerning the etiology of this disease

[1] British Medical Journal, September 14, 1901, p. 687. [2] Ibidem, January 25, 1902.
[3] Memoir, IV., p. 89. [4] British Medical Journal, January 25, 1902.

of tropical climates, nothing has ever been known, although many hypotheses, differing widely, have been advanced. Recently, however, an investigation conducted by Dr. Harris Graham,[1] in the vicinity of Beyrouth, in Syria, implicates the mosquito as an important factor in its spread. At the place mentioned, the disease is very prevalent, and mosquitoes of the genus *Culex* are a serious pest. Graham observed that the disease occurred in persons under observation only when they were bitten by infected mosquitoes, and that, when they were bitten, the disease invariably followed. For example: he applied mosquitoes to a person suffering from it, and, after they had bitten, carried them in a paper box to a village, high up on a mountain, where there was no case of the disease. There they were allowed to bite two apparently healthy persons, in whom, in four and six days, respectively, typical attacks occurred. In a large number of cases, he made examinations of the blood, and in every instance he found in the red corpuscles an amœboid parasite which bore considerable resemblance to the malarial organism, but required a much longer time for its cyclic development and showed no pigment at any stage. The organisms were found at times also in the blood plasma. Flagellated forms were observed also in some cases when the blood had stood for some time.

Further observation and study are obviously desirable and necessary.

Mosquitoes and Distomiasis.—In a recent communication, Dr. F. Martirano [2] gives certain facts which suggest that the principal malarial mosquito may serve as an intermediate host for distomal diseases as well. At the request of Professor Celli, he examined a large number of *Anopheles maculipennis* to ascertain whether the hibernating insects contained malarial parasites in their stomach and salivary glands. Up to the fifteenth day of March, he found from 1 to 5 per cent. of the mosquitoes to be infected, and from that time until the end of May the examination was completely negative. In his examinations it happened frequently that he found in the abdominal cavity a diminutive trematode, which on close study proved to be a distomum. In May and June, fully half of the specimens examined proved to be infested. The distomum was rarely found singly; sometimes five or ten were found in one mosquito. Frequently, they were in the rearmost segment of the abdomen, but he found them also in the salivary ducts. Sometimes they were free in the thorax and in the abdomen, but in the majority of cases they were encysted on the outer wall of the stomach and œsophagus and on the inner wall of the abdominal cavity. The distomum nearly filled the cyst, was very motile, and endeavored to break through its envelope by butting with its forepart. Several times he found not only the distoma, but filarial infection as well. The possibility that the parasite may be communicated to man through the wound made in biting is obvious, and thus may be explained the supposed entrance, through the skin, of *Bilharzia hæmatobia*.

[1] Medical Record, February 8, 1902.
[2] Centralblatt für Bakteriologie, etc., XXX., Dec. 24, 1901, p. 849.

CHAPTER XIII.

HYGIENE OF OCCUPATION.

The influence of occupation on health and length of life has been the subject of much investigation since attention was first called to its importance by Professor Bernardino Ramazzini, of Padua, in 1700, but more particularly during the last half century. Although his work was translated anonymously into English as early as 1705, the subject appears to have been one that did not appeal with any special force to English social scientists and medical men, for the first English work of any importance was that by Mr. C. Turner Thackrah, a practitioner of Leeds, on *The Effects of the Principal Arts, Trades and Professions, and of Civic States and Habits of Living, on Health and Longevity,* published in 1831. A French translation of the work of Ramazzini appeared in 1777, and formed the groundwork of P. Patissier's *Traité des Maladies des Artisans et de celles qui Résultent des Diverses Professions, d'après Ramazzini,* which was published at Paris in 1822. It was translated early also into German; but the first work of any importance on the subject by a German writer was that of Halfort, *Entstehung, Verlauf, und Behandlung der Krankheiten der Künstler und Gewerbetreibenden,* published at Berlin in 1845.

Since the awakening of interest in the subject in England, France, Germany, and other European countries, and the United States, it has been extensively and minutely studied in all its aspects, and to-day its bibliography includes thousands of titles, mostly, however, as would naturally be supposed, of monographs and memoranda pertaining to individual callings. From this vast amount of material from all sources, numerous tables have been constructed, showing, it is generally supposed, how the various occupations stand relatively in the amount of influence which they exert on the longevity of those engaged in them. From these tables it appears, for example, that those who follow some particular calling are more prone to contract certain diseases than those engaged in another; that in each hundred individuals of some one class, a greater number of deaths will occur in a year than in each hundred of another; that the average age at death of those engaged in one employment is lower or higher than that of those in another, and so on.

As in all findings based upon groups of units with, perhaps, but one common bond, each unit being subject to a variety of outside influences, the conclusions drawn from this vast mass of material are influenced largely by fallacy, and include wheat and chaff, fact and fancy. In

many cases, general statements are based upon such a slight foundation as to indicate that their authors are possessed of that degree of genius which has been defined as the ability to generalize from a single instance. In many others, they are based upon facts and conditions which no longer exist, the methods followed in the manufacture of the particular article concerned having undergone a complete change. For example, a process, formerly carried on by men in small establishments run by water-power in the country, may have been concentrated in large mills run by steam and situated in crowded cities; the machinery is different and more perfect, and requires nothing more than feeding, and this may be done by a boy or girl, instead of an adult man. Here, the older facts may no longer apply in any way, and for present purposes should be abandoned as belonging to an extinct occupation.

It is often difficult or impossible in the study of the effects of occupation to eliminate outside influences which may affect the health of the worker as much as or more than the circumstances of his trade. A hundred men, for example, from different strata of society—some married, others single; some living in comfortable houses, others in cheerless, unsanitary tenements; some spending their evenings in wholesome recreation amid wholesome surroundings, others doing evening work in places of public entertainment and elsewhere, or spending their time and wages in the paths of vice; some naturally robust, and others inclined to disease—engage in the same occupation at the same time. During the year, there is considerable sickness among them, and some of them die; perhaps these include mainly young men. Shall it be said without a careful analysis of all the circumstances of their lives and of the immediate causes of their deaths, that their calling is necessarily inimical to health and longevity? This one died of smallpox; this one of consumption; this one of a blow on the head while drunk; this one was drowned; two were victims of typhoid fever and two of pneumonia; eight in all—truly a large percentage, but shall the trade be blamed?

It must, of course, be self-evident that certain occupations are intrinsically dangerous to health, because of the nature of the substances with which the workers are brought in contact; and these are properly classed as dangerous trades. Many others are so classed, not because of any intrinsic danger, but on account of the peculiar conditions under which they are ordinarily carried on, these tending to reduce the physiological resistance to disease. Still others are classed as dangerous to health which are merely dangerous to life, the individual being subject to mechanical violence while in the enjoyment of perfect health. These also are properly to be included among the dangerous trades. But the great majority of callings are neither intrinsically dangerous nor carried on under peculiar conditions favoring a low state of health, yet many of these figure in statistical tables in such a way as to lead to the conclusion that those engaged in them may have little hope of green old age, while others in occupations of practi-

cally the same character, but under different names, give promise of a full period of usefulness.

Statistical tables of longevity of groups of individuals engaged in the various callings should be used with much circumspection and with a due regard to the various circumstances which determine the choice of trade, the age of the individual at the time of engaging upon it, the length of time which one may serve before engaging in another, the peculiar conditions under which the calling is pursued, and the probable character of the influences which affect the well-being of the individual while he is not immediately engaged; that is to say, his home surroundings, his personal habits, the nature of his relaxations, the quality of his food, and other factors. Tables based on foreign statistics should, furthermore, be not too freely accepted as applicable to home conditions, owing to differences in racial peculiarities and of conditions under which those engaged work and live, for one can hardly suppose that any one class works and lives under the same conditions in all countries.

The conditions which govern the choice of an occupation are of very great importance. Many callings demand men of robust build and good health, and manifestly are unsuited to the weakling, who naturally is attracted to other occupations of a lighter character. On this score alone, statistics may be grossly fallacious. For example, in certain tables it will be observed that the class designated as clerks have a low average age at death, and from this it may be inferred that the calling is one which is intrinsically incompatible with long life. But is it fraught with danger? Is it conducted under peculiar conditions which tend to bring its unfortunate followers to an early grave? Or is it not rather the fact that it is the refuge of a great number of those whose physical powers are such that they are unsuited to employments which call for greater robustness, and who, inevitably marked for an early death, regardless of their calling, reduce the average age at death of the entire class.

On the other hand, certain occupations involving much severe muscular effort appear to be conducive to long life, in spite of the conditions under which they are pursued. Here must be borne in mind that in these, the weaker individuals and those whose powers begin to fail are forced into other occupations, and that those who remain until the end show an average age at death which is eloquent of the benign influence of the calling. It is undoubtedly true that muscular effort, carried to excess, will undermine the health; but not forced beyond reasonable limits, and particularly if carried on under good hygienic surroundings, instead of being in itself prejudicial to health, is promotive of it. Those who are forced into lighter occupations may find the change advantageous; or, on the other hand, entering upon them already broken in health, may help to reduce the average age at death of all those engaged therein.

Another influence having a bearing on the choice of occupation is the high wage offered to attract workmen to trades which are properly

conceded to be dangerous to health. These are naturally unattractive to men of sound body and mind, to whom health and life are sweet, and hence they find their recruits among the broken-down and vicious, to whom the rate of pay offers, in the one case, immediate much-needed and otherwise unattainable financial relief, and, in the other, opportunity for a short period of unrestrained license.

Statistics concerning occupations entered upon at an early age and followed for but a limited number of years as a preliminary training for other callings, and those which from their very nature demand men of wide experience, hence well matured, can be of little or no value unless the occupations are in some way of intrinsic danger. We find, for example, in certain statistical tables dealing only with individuals above the age of 20 years, that the average age at death of students is about 23 years, while that of professors exceeds 50. The manifest absurdity of attempting comparisons of the healthfulness of these two occupations is brought out still farther by reversing the case, and supposing the professors to die off at 23 and the students at 50. Since even advanced students in the professional schools pass, as a rule, out of the student class and into their chosen fields of usefulness long before their thirtieth year, it cannot cause surprise that those who die before their training is completed do not show a high average age at death; and, on the other hand, since men of learning are not ordinarily called upon to assume the duties of professors until they have passed through the lower grades which lead to that rank, it is to be expected that their average age at death will be fairly high. To compare lieutenants and major-generals, shipping-clerks and retired merchants, apprentices and master carpenters, would be no more absurd. The average age at death of any one calling must be largely influenced by the relative number of individuals of the different age periods engaged therein, just as is the case with the population in general.

Another fact that affects the age at which work is undertaken is a very low wage offered even in times of prosperity, so low as to be no inducement to heads of families, but sufficiently high to cause them to help out their financial condition by making use of their offspring.

Before proceeding to a classification of occupations according to the circumstances which determine their healthfulness, it is desirable to consider the significance of the somewhat loosely applied term, *occupation diseases.* Every form of occupation and every form of life of leisure has some attendant circumstances which may at some time, in one way or another, bring about a predisposition to some form of disease; and to regard every disease of an artisan, tradesman, or professional man as attributable to his particular calling, is to fall into a common inexcusable error, for workers and drones have most diseases in common. It is beyond dispute that certain pathological conditions are caused and others promoted by certain occupations, and it is equally true that most diseases already acquired may be influenced for better or worse by one or another calling.

The true occupation disease is that which in all probability would not have been acquired had the individual not engaged in his particular calling or some other in which the conditions are essentially similar. As an instance, may be cited the lead paralysis of the house painter, potter, compositor, and file-cutter. Certain diseases of common occurrence in the population at large are promoted by the conditions under which various callings are carried on, but these cannot properly be called occupation diseases, since the exciting cause is in no way a part of the business, and under better hygienic management, combined with more favorable outside influences, might be avoided. As a conspicuous instance of this class, may be cited the tuberculosis of dressmakers, cutlery grinders, and operatives in the cotton and flax industries, promoted by overcrowding and inhalation of dust while at work, and by all extraneous conditions tending to lower vitality. The plying of the needle is in itself in no way inimical to the integrity of the lungs; the grinding of the steel implement on the wheel and the running of the loom send forth none of the specific bacilli; but the overcrowding in the one case, and the unavoidable inhalation of irritating dust in the others, bring about the conditions which offer fertile soil to the germ of the disease.

Certain conditions are influenced for better or worse by different occupations, as has been stated. Among these may be mentioned anæmia, which not uncommonly is classed among the diseases of occupation. Under the conditions of many indoor callings, this state is easily brought about, or, if already existing, increased; but, on the other hand, under those of outdoor occupation, it is not likely to be induced, and, if already existing, may be made to disappear. Many occupations, for easily explainable reasons, draw their workers largely from that portion of the population which is, if not already diseased, predisposed by heredity, habit, and home surroundings to anæmia, tuberculosis, and other disorders, the onset of which may be hastened or delayed, according to circumstances. In these, and in occupations in general, it is not an easy matter to determine correctly the amount of influence properly chargeable to the calling when disease appears, since the conditions under which a trade is carried on may be widely variable, and their influence for good or evil exceedingly complex. Among these conditions may be mentioned indoor confinement, nature of materials, geographical location, and wages paid.

Whether an occupation is carried on indoors or outdoors, is of much importance, for, other things being equal, outdoor employment is far more conducive to health than is confinement, even in well-ventilated factories, in which, with the best of systems, the air cannot be maintained in the condition of purity which obtains outside. Even those callings which subject their followers to great vicissitudes of weather appear to be more conducive to robustness than those carried on indoors, particularly if the nature of the work is such as to call for freedom of movement and great bodily activity. The sailor, the letter-carrier, or the farm hand, for example, working in the open

air, in heat and cold and in all kinds of weather, is better circumstanced in many ways than the loom-tender, the entry clerk, and the salesman at the ribbon counter. He works, perhaps, in a broiling sun, rather than in an overheated room filled with impure air; the air he inhales contains some dust, perhaps much, but it is a less harmful dust, less abundant, and not continuous. The air of the factory and workshop may be almost as pure as that out of doors, or it may be laden with fumes, gases, foul odors, or dust of a special nature, according to the materials used. The outdoor worker is also much less oppressed by the monotony which is so conspicuously a concomitant of indoor work. He can, at least, see some part of his world in ever-changing conditions, while the mill operative tends his machine, of which he is perhaps only a minor part, day in and day out, seeing it do the same thing with mechanical exactness so many times per minute or per hour, with no more sense of responsibility than might reside in an automaton.

Geographical location of the place of employment has an important sanitary bearing on the condition of the workers, since it determines very largely the outside influences to which they are subjected. Location in country districts is likely to insure better and cheaper homes than can be found in crowded cities, with, perhaps, a patch of garden which may be worked for pleasure, profit, and variety in the diet. It is, furthermore, farther removed from the influence of the tippling-shop and other unhealthy influences of the city.

The wages paid affect the health of the working classes in several ways. A small wage means necessarily a small expenditure for rent, clothing, and food; it means overcrowded tenements, lack of ventilation, insufficient protection of the body by clothing of inferior quality, inadequate food—usually improperly prepared and hastily bolted—personal and general uncleanliness and other conditions which lower the mental, moral, and physical well-being of the workers and all who are dependent upon them. It means more beside: it means the utilization of child-labor and the breaking-down of women, who perform the double duty of looking after the home and assisting in its maintenance. All these circumstances promote the morbidity- and mortality-rates, and the particular occupations, perhaps intrinsically wholesome, are then said to be inimical to health, when it is not the nature of the callings, but the attendant circumstances, that are at fault. Thus, it often happens that the conditions leading to the most serious evils may be traced to some circumstance or combination of circumstances which are wholly external.

Classification of Occupations.—In a general way, we may, from a sanitary standpoint, classify occupations as follows: 1. Those which are intrinsically dangerous to health by reason of the nature of the materials involved. 2. Those which are carried on under conditions, avoidable or unavoidable, which promote susceptibility to disease. 3. Those which, involving exposure to mechanical violence, are dangerous to life and limb rather than to health. 4. Those neither intrinsically

dangerous to health or life nor carried on necessarily under peculiar avoidable or unavoidable circumstances.

The first and second of these classes are of especial interest to the sanitarian, whose efforts are directed toward the removal of all unsanitary influences of whatsoever kind attending any and all occupations. The third class includes occupations which involve the possibility of injury due to circumstances bearing no relation to hygiene. Thus, no effort of the hygienist can prevent a brakeman from falling beneath the wheels of a train or the operatives in a dynamite industry from being blown into eternity by the force of an explosion due to carelessness. The fourth class—and this includes a great variety of perfectly colorless callings—presents nothing of especial hygienic interest, since the physical condition of the individual would be essentially the same whether he were engaged in one or another of the different fields, and only those which are carried on under peculiar conditions can be studied to advantage. Therefore, only the first two classes will be considered here, and since the dividing line between the two is often difficult to define, and since some occupations may be said to belong to both, the two may be merged into one for the sake of convenience, and then subdivided as below:

The occupations which are of particular hygienic interest embrace those which involve exposure to—

1. Air vitiated by respiration.
2. Irritating and poisonous gases and fumes.
3. Irritating and poisonous dusts.
4. Infective matter in dust.
5. Offensive gases and vapors.
6. Extremes of heat.
7. Dampness.
8. Abnormal atmospheric pressure.

Of distinct, but minor, importance are those which involve—

9. Constrained attitude.
10. Over-exercise of parts of the body.
11. Sedentary life.

Some occupations are conducted under such conditions that they may very properly be regarded as belonging to a number of these groups. Mining, for example, may be considered under groups 2, 3, 6, 7, 9, and 10, and cigar-making under groups 1, 2, 3, 9, and 11.

To attempt to describe the conditions which surround each individual industry, and to give the details of the countless processes involved, would be beyond the scope of a work of this nature, and quite unnecessary for a general understanding of the relation of occupation to health. Therefore, in the following pages, only the most conspicuously characteristic examples will be cited by way of illustration of the dangers to which workers are exposed.

1. Occupations Involving Exposure to Air Vitiated by Respiration.

This class may be made to include any indoor calling carried on in overcrowded, ill-ventilated rooms, in which the air is vitiated only by the processes of the body, and not by adventitious gases or dust. These occupations, therefore, are not in themselves dangerous, but are made so by a preventable cause.

As examples, may be cited the callings of tailoring and dressmaking, which, only too commonly, are conducted in rooms in which fresh air and cubic space per capita are at a minimum. The workers are packed into quarters no larger than absolutely necessary for the performance of their daily task, impossible of proper ventilation without an expensive mechanical system, so great is the overcrowding, and, as is naturally to be supposed, overheated. Here, the unfortunates spend a fairly long day, leaving at night to go to homes perhaps no less unsanitary. If not already so when they begin, they become, after a time, anæmic, dyspeptic, and depressed, these conditions, as in many other callings, being promoted by lack of exercise, by ill-chosen and badly cooked food, and by absence of healthful recreations. They become greatly susceptible to cold, and hence opposed to the admission of fresh air from without. Breathing excremental air by day and night, denying themselves proper food, their minds depressed, it is not to be wondered at that their condition invites disease, more particularly the one which stands forth conspicuously as a consequence of overcrowding; namely, pulmonary consumption. The onset is insidious. Beginning with a cold that resists being "thrown off," the cough becomes chronic; they continue to lose weight and strength, and the end can be foreseen. It is not to be understood that these callings are always or even usually associated with these conditions; but when they are, the result is generally the same.

2. Occupations Involving Exposure to Irritating and Poisonous Gases and Fumes.

This class includes a great variety of callings which may or may not be intrinsically dangerous, according to individual circumstances. In many cases, the danger may be much lessened by due regard to personal hygiene and by the use of respirators. These are simple pieces of apparatus designed to remove noxious matters from the air, on its way to the respiratory passages. It is the rule, however, that workmen refuse to wear them after the first days, even though well aware of the possible consequences of laying them aside. One reason for this is that not one of the several forms invented can be worn with any degree of comfort. They demand faster respiration, soon get wet with expired moisture, and cause excessive perspiration. Furthermore, they cannot be made to fit tightly, and so, even when conscientiously worn, they only partially perform their office. The

majority of them are designed to filter out dust, but all are made on essentially the same principle, those intended for noxious fumes containing spongy or other absorbent material, wet with agents which exert a neutralizing influence.

One form consists of a muzzle of fine wire gauze, single or double, on a metallic frame. If made with a single layer, it is lined with cotton-wool, kept in place by a very loosely woven fabric stitched to the wire meshes; if made double, the intervening space is occupied by a piece of thin flannel. Another form is made of woven or knitted stuff, instead of wire. This is said to be even hotter than the first mentioned, particularly in summer, and both are extremely uncomfortable. A third form, made of pieces of flat sponge large enough to cover the nose and mouth, interferes very much with free respiration. Another, consisting of a large bag of fine cambric, is said to be less objectionable, but is difficult to fasten tightly.

Aside from the discomfort caused by respirators of whatever form, the operatives have another, a senseless, objection to their use, women complaining that they are made to "look ridiculous," and men being moved to discard them by the gibes of their more reckless fellows.

(*a*) **Irritating Gases and Fumes.**—As examples of irritating gases or fumes, may be cited ammonia, chlorine, sulphur dioxide, hydrochloric acid, and nitrous fumes. In small amounts, they cause, perhaps, no more disturbance than a slight tickling cough, but in large amounts, they bring about great discomfort and acute and chronic catarrhal conditions.

Chlorine, which is used or given off very extensively in a number of industries, is unimportant when it is present in the air in very small traces; but when in large amounts, it is said to cause minor catarrhal troubles and diminution or even loss of the sense of smell. It is said by Pettenkofer that from 1 to 5 parts of chlorine in 100,000 of air are sufficient to affect the lungs; that 40 to 60 parts in 100,000 will produce alarming symptoms; and that more than 60 parts will cause death. It is given off in the processes of making and using bleaching powder, in the operation of glazing bricks, and in various other processes. Among the workmen who make use of bleaching powder, the occurrence of bronchitis, asthma, and caries of the teeth, is noticeably frequent.

Hydrochloric acid fumes are given off in various industries, and especially from alkali works, the immediate neighborhood of which is likely to be barren of vegetation in consequence thereof. They are given off also in the process of galvanizing iron, the first part of the work consisting in "pickling" the iron in the acid to clean it and to prevent the presence of oxide on the surface when it is dipped into the molten zinc. These fumes act much less energetically on the respiratory passages than chlorine. Pettenkofer states that as much as 1 part in 1,000 of air can be borne without difficulty by men who are accustomed to it, but that this amount cannot be exceeded. In the galvanizing process, the workmen are exposed also to the dense fumes arising

from the sal ammoniac which is, from time to time, thrown upon the surface of the molten zinc. These are more insupportable than the acid fumes.

Sulphur dioxide is evolved in the smelting of various ores, in preparing hops, in the manufacture of sulphuric acid and of ordinary matches, and is used extensively as a bleaching agent. In small amounts, it causes cough, and, by those unaccustomed to it, cannot be tolerated. Those who are exposed to it in their daily work establish a gradual tolerance and take no notice whatever of an atmosphere in which it is present to such an extent that persons unaccustomed to it cannot breathe it. The weight of evidence concerning the relation of this gas to health indicates that its effects are neither serious nor lasting, and are exerted more on the digestive than on the respiratory function. In some individuals, a small amount in the atmosphere causes epigastric pain and heartburn very quickly.

Bromine is exceedingly irritating to the respiratory passages and to other mucous membranes with which it may come in contact. In small amounts, it causes cough, dizziness, and a feeling of general malaise; in large amounts, spasm of the glottis and asphyxia. Bronchial asthma is commonly observed among those constantly exposed. The fumes of iodine act practically in the same way, although to a much less marked extent. In occupations in which these two substances are used, men with a tendency to pulmonary troubles should not be permitted to work.

There is no evidence that ammonia in small amounts produces anything more than temporary irritation of the air-passages, but it is a general belief that it is conducive to emphysema.

Nitrous fumes, given off in a number of processes involving contact of metals with nitric acid, are also of no very great importance in small amounts, but it is said that those who are exposed are especially subject to phthisis, in the causation of which it is conceded that the constrained attitude and lack of ventilation have a large influence. It is noted that the tendency is greatest in those exposed to the largest amounts.

(*b*) **Poisonous Gases and Fumes.**—This class includes a very large number of occupations, since poisonous gases are an incident of processes without number.

Carbon monoxide is one of the most important of the poisonous gases, and this is given off in many manufacturing operations, usually in company with other gases, and it is, therefore, not always an easy matter to determine what proportion of the effects noticed are due to any one constituent of the mixture. The constant inhalation of even very small amounts of carbon monoxide causes disturbances of the digestive function, general weakening of the system, and diminished mental power. The one class in which one would naturally expect to find the greatest evidence of injury, namely, laborers in gas plants, yields very little.

Carbon disulphide is much used as a solvent for fats, but its chief

use is as a solvent and vulcanizing agent for India-rubber. The very peculiar effects produced upon the operatives in rubber factories, especially when the work is carried on in imperfectly ventilated rooms, have been attributed generally to the use of this agent. There is at first a dull headache, which increases much in severity toward the close of day; sight becomes somewhat confused; vertigo and epileptiform convulsions, pains in the extremities, and formication are common. In the early stages, an unrestrainable inclination to talk is almost invariably observed, and, coincidently, a stimulation of sexual desire. Soon, the victim becomes moody, irritable, and subject to violent outbreaks of anger; vision becomes further impaired; the sense of smell is much diminished. During this stage, obstinate insomnia is the rule. Next occurs a stage of depression, in which the loquacity and increased sexual desire give way to impaired memory, feebleness of mind, taciturnity, and diminution of sexual desire and power even to complete abolishment, with intense headache, either somnolence or wakefulness, and local areas of anæsthesia. Sometimes cough, dyspnœa, and paraplegia are observed. As a rule, however, no permanent injury is caused, since, from the very nature of the symptoms, the victims are unable to continue to work; and removal from the cause, with appropriate medication, in which phosphorus is highly regarded, usually brings about a perfect cure. This train of symptoms seems to be peculiar to workers in rubber factories; and since the evidence at hand shows that those who make carbon disulphide do not suffer in the same way, it seems reasonable to suppose that other agents than this one are to be considered in the etiology. It happens that, in this same industry, naphtha is very much used as a solvent. The vapors of this substance cause embarrassment of respiration, and also dizziness and mental confusion. In France, the employment of women under eighteen in rubber factories, and in any work which exposes them to the combined fumes of naphtha and carbon disulphide, is prohibited. Santesson[1] has reported 9 cases of naphtha-poisoning, 4 of which were fatal. They occurred in a rubber factory where a solution of rubber in naphtha was used. The symptoms were headache, dizziness, vomiting, palpitation, and hemorrhages. In those cases which recovered, the symptoms lasted several weeks. All the victims were young women. In 1 fatal case, the autopsy showed fatty degeneration of the heart, liver, kidneys, and other parts. Naphtha is used very extensively also in cleansing woollen and other unwashable clothing, and young women employed in establishments devoted to this kind of work suffer from dizziness, nausea and vomiting, headache, insomnia, and hysteria. They find it necessary to go frequently into the open air in order to avoid hysterical outbreaks.

Another much more poisonous substance is nitrobenzol, which is very insidious in its effects. It is used in making aniline, like which it is a narcotic poison, and in the manufacture of roburite and other

[1] Gazette hebdomadaire de Médecine et de Chirurgie, August 26, 1897.

of the newer explosives. Long exposure to small amounts produces a train of symptoms which include headache, dyspnœa, drowsiness, dizziness, nausea and vomiting, and loss of muscular strength, and which terminate in stupor and not infrequently in death. Death sometimes occurs within a few hours of the onset. Aniline vapor itself is dangerous to health when present in the air to the extent of 0.1 per cent.

The most prominent of all the poisonous vapors in manufacturing processes are those of mercury and phosphorus. It is hardly necessary here to enumerate the effects of exposure to these poisons, since they are so universally well known; but it is not so commonly recognized that operatives in industries in which metallic mercury is used extensively appear to be very subject to phthisis, and that, among the women, miscarriage is very common. It is said that the offspring show the effects of the poison, and that two-thirds or more of those born at term die without completing a year of life; but it is well to consider that among the classes from which the operatives for this and similar occupations are drawn, child life, at best, labors under great disadvantages.

Mercury is commonly supposed to be used chiefly in the manufacture of mirrors, and in gilding and silvering. This, however, is far from being the case. In fact, the processes of making mirrors and of gilding have been so revolutionized that, in these industries, mercurial affections have been practically eliminated. At present, one of the most common sources of mercurial poisoning is the industry of felting, in which it has been discovered that the coney and other hairs used make better felt, if they have a preliminary treatment in a bath of mercuric nitrate. In a later process, the raw product is heated to a temperature sufficient to volatilize the mercury. Other occupations in which mercury is used extensively include the manufacture of thermometers, barometers, and certain forms of electric batteries, and the bronzing of plaster casts with an amalgam containing tin, bismuth, and mercury.

Phosphorus is a substance of much more importance to the public health than mercury. The only industry of any magnitude in which phosphorus is used extensively is that of match-making, in which industry the operatives suffer from the well-known lesions which phosphorus produces. This is a danger which has received much legislative attention in England and other European countries, and much has been done to avert it by more strict attention to hygiene and the introduction of machinery to take the place of human beings. In Switzerland, indeed, even the use of any matches other than those made with amorphous phosphorus is absolutely forbidden.

Common phosphorus gives off poisonous fumes at ordinary temperatures, provided the air contains moisture. Amorphous, or red, phosphorus is not poisonous, and gives off no fumes under usual conditions. It cannot be used in the same way as common phosphorus, and is employed only in the manufacture of matches that strike only on the box or on a specially prepared surface; this is obviously a

disadvantage, since a match that will strike anywhere is much more convenient. It is said that, in England alone, no less than 60 tons of white phosphorus are consumed annually, against 4 tons of the red variety.

It is a very common notion that most of the workmen suffer extensively from the effects of the poisonous fumes, and that necrosis of the jaw is exceedingly common. It appears, however, that, while this class of workmen are in general anæmic and badly nourished, the extensive lesions that formerly were noticed have been of late years much less common. In 1897–8, in the United Kingdom, more than 1,500 persons were engaged, but in the four years, 1894–8, only 36 cases of necrosis of the jaw were recorded, 21 of which occurred in 1890; but possibly more may have occurred. This reduction is due to precautions taken to carry off the fumes by thorough ventilation, and to prevent their production as far as possible by the use of substances like turpentine, and by drying the matches as quickly as possible after they have been dipped, since the fumes are given off only in the presence of moisture. Again, much of the work of dipping is done in closed hoods. It is said that the most difficult part of prevention lies in the handling of the work-people themselves, since they are of a class that can rarely be made to understand the importance of cleanliness and of attention to the condition of the teeth. Persons with decayed teeth should be excluded from the business, since caries is known to increase enormously the risk of poisoning. They cannot, for reasons already explained, be persuaded to use respirators.

In the industry of brass-founding, fumes are given off which cause what is commonly known as "brass-founders' ague," which is a disorder occurring sooner or later—usually, within a very short time—to all engaged. The trouble begins with a feeling of malaise, headache, stiffness, great muscular pain, and soreness of the chest. A chill comes on, which lasts generally about a quarter of an hour, after which the patient falls into a profuse perspiration. The symptoms then begin to abate and within a day or two disappear. Although this train of symptoms does not commonly recur, a more or less marked chronic poisoning is common, in which the most prominent symptoms are anæmia, cough, tachycardia, headache, neuralgia, disordered digestion, progressive emaciation, and annoying eruptions of the skin. The acute and chronic poisoning suffered by this class of workmen are supposed by some to be due to zinc, by some to copper, by some to both together, and by others to arsenic, which is an important constituent of some kinds of brass and an impurity of others. Some incline to the belief that brass-founders' ague is a true infection, for which the poisoned air prepares the ground and paves the way.

Fumes of arsenic are given off in various smelting operations, but the chief danger from this substance is met with in occupations to be considered later, in which it is given off in the form of dust. A peculiar source of poisoning by arseniuretted hydrogen has been brought to public notice by Maljean,[1] who observed a number of cases of icterus

[1] Archives de Médecine militaire, February, 1900, p. 12.

among the balloonists of a regiment of engineers. The cause was traced by him to the hydrogen gas used in filling the balloons, which was made by the action of ordinary commercial sulphuric acid on commercial zinc, both of which contain arsenic in variable amounts, in consequence of which the product contained arseniuretted hydrogen. The impure gas was liberated through the valve of the balloon, but the main source of danger was the habit of smelling at the stopcock during filling, to ascertain when the air in the pipes had been expelled by the gas. In the cases observed, the onset was marked by great malaise, headache, nausea, stiffness of the joints, jaundice, and hæmoglobinuria. The symptoms subsided in a few days, leaving the patients in a condition of anæmia and pronounced malnutrition.

The vapors of wood alcohol have within recent years attracted considerable attention by reason of their disastrous effects upon vision. Since 1899, many cases of blindness have been reported in the journals devoted to ophthalmology as due to the vapors and to the internal use of preparations such as essences of ginger, peppermint, etc., which are very commonly made with wood alcohol, and extensively consumed in places where the sale of liquor is prohibited. When wood alcohol as such is consumed, as it often is, with fatal results, it will be noted that the victims are generally quite blind before death approaches. Würdemann[1] has reported a case of wood-alcohol blindness due to the inhalation of fumes from varnish. The subject was a moderate user of tobacco and stimulants, whose sight had always been good. After working six days, he was obliged to quit work on account of nausea, dizziness, and severe frontal headache. On the following day, he had dimness of sight, and then became totally blind for twenty-four days, when his sight began to improve. In another case reported by Patillo,[2] and quoted by Würdemann, the material worked with was the same, and total blindness occurred on the sixth day. This lasted a week, then sight improved, but in two weeks it began again to fail. Inhalation of the vapor is believed to cause retrobulbar neuritis, producing partial atrophy of the optic nerve, especially of the central fibers.

3. Occupations Involving Exposure to Poisonous and Irritating Dusts.

Dust is of very great importance in its influence on health. Its production is a prominent feature of many occupations, in some of which so much is caused as to be of the highest possible importance. It may be divided into poisonous and irritating, and the latter may be subdivided into mineral, metallic, vegetable, and animal.

(*a*) **Poisonous Dusts.**—The most important of the poisonous dusts are arsenic and lead.

One of the most dangerous of arsenical trades is the grinding of the well-known green pigments, Scheele's green (arsenite of copper) and

[1] American Medicine, December 21, 1901, p. 995.
[2] Ophthalmic Record, December, 1899, p. 599.

Schweinfurt green (aceto-arsenite of copper). These and many other arsenical colors are used in printing wall-papers, cretonnes, and other decorations, and in the manufacture of artificial flowers. The latter is an especially dangerous occupation, since after the leaves have been cut to the proper shape, they are smeared with gum, the green pigment is then dusted on from a dredging-box and much of the substance becomes suspended in the air. Much of the green glazed paper used for covering boxes is made with these pigments, and other papers and articles of paper in green and other colors (playing cards, etc.), are made with arsenical pigments. Arsenite of sodium is a very common mordant, and white arsenic is much used in taxidermy. In fact, the list of processes in which arsenic is used is almost endless. The symptoms produced may be acute, but ordinarily are chronic in character. Workmen of this class frequently suffer from eczematous sores and obstinate ulcers. The symptoms of chronic poisoning are too well known to need description.

Lead is infinitely more disastrous in its effects upon health, and is by far the most important of all industrial poisons, because of the great diversity of its use. Among the many occupations in which it figures may be mentioned all the processes involved in obtaining lead in its commercially pure state from ores, the making of white and red lead, the glazing of many kinds of papers; type-founding and setting, glass-cutting and polishing, file-cutting; enamelling, dyeing and printing, working in weighted silk; plumbing, painting, leather varnishing; making artificial flowers, leaves, and jewels; and several of the processes used in the making of earthenware and china. In many of these, the lead gains access to the system through inhalation, and in some it is carried into the mouth by the soiled fingers. The latter method of introduction is very commonly the case with compositors, plumbers, workers in lace and silk weighted with lead acetate, and others.

In Paris alone, it is said, there are more than 30,000 of the working classes following callings which expose them to this very deleterious substance. In England, the great importance of the subject of industrial lead-poisoning has led to extensive investigations, resulting in stringent legislation; and in the year 1895, it was required that all cases of lead-poisoning should be reported to the authorities. During the year 1897, the number reported was 1,124, and in 1898, 1,278. The largest number of cases are reported from the china and earthenware trades. It appears to be a fact, wherever the matter is investigated, that women suffer less than men. This is explainable in two ways: first, that women are naturally more cleanly in their habits; and second, that women are more likely to give up their work after the occurrence of the first symptoms and before the affection becomes chronic. Men appear to be able to work longer without showing evidence of injury.

Particular attention has been given of late years in England, France, and elsewhere to the pottery industry, in which lead is used in the

glazes, the flux being made of litharge, clay, and flint. Much attention has been given to the possibility of finding a glaze which shall be free from lead. In the manufacture of ordinary white porcelain, no lead glaze is required, and the danger of lead-poisoning arises almost wholly in the work of decoration, the powder which is dusted on and off the transfer paper, containing lead compounds. According to a report of a committee of the master potters of Staffordshire, it is not possible to substitute a leadless glaze for ordinary china and earthenware, but this is said to be only partly true.

In Limoges, where 16,000 people, of whom 2,500 are children, are employed in sixteen pottery establishments, the workers are much less subject to lead-poisoning than those in Staffordshire, and in one of the establishments where the ware produced is of the same kind as made in Staffordshire, the glaze contains only 8 per cent. of lead carbonate against 13 to 24 in that used in Staffordshire. It has been pointed out that where lead glazes are necessary, the danger can be very much diminished, if the lead is used in the form of a double fritted silicate. In the Limoges factories, the lead is used in this condition, and to this fact, part of the difference in the amount of poisoning is probably due. In English potteries, the tendency is toward the abandonment of the old methods and the adoption of fritted lead.

Lead is, however, not the only danger to health with which workmen in potteries have to contend. In certain of the operations, large amounts of mineral dust are given off, and in consequence they suffer from the effects of not only poisonous, but irritating, dust; in fact, the occupation is regarded from a sanitary standpoint as one of the least desirable. The flint-grinders, who belong to this class, are, according to Hirt, quite low down in the scale of longevity. It is said that the dust which is given off in the operation of grinding kaolin is unusually irritating to the lungs—worse, even, than steel dust. The most common diseases among potters are bronchitis, phthisis, rheumatism, and lead-poisoning.

As another example of an industry in which the workmen suffer largely from lead-poisoning may be cited that of file-making, in which, as in pottery-making, the operative is subjected to the action of dust both poisonous and irritating. The best files are those cut by hand, no machinery having yet been invented to produce so satisfactory an article as the hand-made. While being cut, the file is held upon a leaden bed, called the "stiddy," which offers sufficient resistance to the blow, without at the same time being so unyielding as to cause a recoil. As fast as it is cut, it is brushed off, and the air becomes charged with a combination of steel, lead, chalk, and charcoal, and granite from the block, or "stock," upon which the "stiddy" is secured. The danger of lead-poisoning is thus always present, and its occurrence is hastened by the careless habits of the workman, who, in handling the leaden bed, constantly wets the thumb and forefinger of his left hand with his tongue. Doubtless, if more attention were paid to personal hygiene, a smaller proportion would suffer from colic and

paralysis of the extensor muscles of the wrist and thumb. It is said that a robust file-cutter is rarely seen; as a class, they are sallow, anæmic, and dull, and the majority show the blue line of chronic lead-poisoning.

A more modern industrial danger is that involved in making and charging storage batteries of a certain kind. Dr. Talamon[1] relates that, during a single year of hospital service, he saw 30 cases of lead-poisoning among workmen so engaged. The work consists largely in spreading red lead and litharge over lead plates with the bare hands, and the results on the system are doubtless due in greatest part to absorption through the alimentary tract, the lead being conveyed to the mouth by the hands. The symptoms come on much more rapidly and are much more acute than with painters, type-setters, and others. Many of the men fall victims within three or four weeks from the beginning of their service.

(*b*) **Irritating Dusts.**—The irritating dusts act with variable intensity, according to their nature. It is generally thought that that of vegetable origin is the most irritating of all; then, in order, metallic, animal, and mineral. The disease which is conspicuously common among dust-workers—more common than among any other large class—is phthisis, a predisposition to which is favored by constant irritation by the dust, assisted by poor ventilation, constrained attitude, and other unsanitary circumstances. In general, the first effects of an abnormal amount of dust in the air are cough and increased secretion of mucus. Then the cough becomes chronic, and when the soil has been properly prepared, the specific bacillus finds a lodgement and soon produces its results. Many of the dust-workers' disorders are traceable not to a single kind of dust, but to a mixture. Thus, the condition formerly known as "grinders' asthma" is superinduced by a mixture of metallic particles from the implement ground and mineral matter from the stone, and to which, if either, of the two kinds the prepondering influence belongs, cannot be stated.

The relative frequency with which diseases of the lungs occur in the different classes of dust-workers and in those whose occupation creates no unusual amount of dust was determined by Hirt[2] from a large mass of material, in which, of course, the value of the primary factors can hardly be determined; nor that of collateral circumstances, such as habits, heredity, and locality. But his facts, which, to say the least, are coincidences of occupation and disease, show that the different classes of dust-workers suffer from pneumonia and phthisis in varying degrees, and much more frequently than those not exposed to dust, and that in the frequency of diseases of the digestive system, on the other hand, there is practically no difference. In the following table, compiled from his figures, the relative frequency of these diseases per 100 workmen is shown:

[1] La Médecine moderne, Feb. 7, 1900.
[2] Die Krankheiten der Arbeiter, Breslau, 1871.

	Pneumonia.	Phthisis.	Digestive disorders.
Workers in metallic dust	17.4	28.0	17.8
" " mineral "	5.9	25.2	16.6
" " vegetable "	9.4	13.3	15.7
" " animal "	7.7	20.8	20.2
" " mixed "	6.0	22.6	15.2
" " non-dusty trades	4.6	11.1	16.0

With regard to the influence of the different kinds of dust occupations, one must not lose sight of the fact that quantity as well as quality should be considered, and that local conditions of ventilation have a very decided bearing.

Among the occupations in which metallic dust is given off in notable amounts, that which stands forth most conspicuously as dangerous is steel-grinding. In this work, the danger varies inversely with the size of the object ground; that is to say, the smaller the object, the greater the danger. This is because large objects can be ground in the wet way, but very small ones, as needles, must be ground dry and require constrained attitude and close inspection, and thus the grinder constantly inhales the very fine, sharp particles of steel that are thrown off in the process. These, by constant irritation of the mucous membranes of the air-passages, prepare them for the reception of the specific organisms of pneumonia and phthisis. At first, the cough is dry, but in a short time is accompanied by expectoration. Among those individuals who have followed the work for a year or longer under the usual conditions, a sound man is rare. Their average age at death is stated variously between twenty-five and forty years. The danger may be much reduced by the use of respirators, and by the employment of a blast of air to carry the dust away from the grinder into an appropriate exit.

Not all metallic dust is as irritating as that given off in cutlery-grinding, and in some occupations in which it is given off even more abundantly, there is no noticeable tendency to phthisis, although, perhaps, the subject has not been investigated with sufficient thoroughness. In the operation of bronzing in the manufacture of show cards, Christmas cards, and the like, the bronze powder, which, under the microscope shows sharp angles, is applied to the pattern, printed in sizing, by means of a soft pad worked largely by hand. The dust adheres tenaciously to the skin and causes much local irritation, and is inhaled and causes catarrh of the upper air-passages. In addition, the workers suffer from headache, bad taste in the mouth, anorexia, nausea, vomiting, and diarrhœa, from absorption and local action in the alimentary canal. When the operations of dusting on and off are done by machinery, the evolution of dust is very much lessened.

The dusts of many of the metallic salts produce more or less serious local effects, aside from the results due to absorption into the system. In the manufacture and use of potassium dichromate, for example, great irritation of the nasal mucous membrane is caused, followed by ulceration, which in most instances ends in perforation of the septum.

Ulcers are produced wherever the skin is abraded, and especially on the scalp, where action is promoted by the scratching which the irritation calls forth. No local effects appear to be caused in the lungs.

As an example of a calling in which mineral dust is given off in abundance, that of glass-grinding may be mentioned. This is much like cutlery-grinding, in a general way, and the dust produced is nearly, if not quite, as sharp and irritating. In addition, the workmen are often subject to lead-poisoning, due to the use of putty powder containing 70 per cent. of lead oxide. It is as rare to find sound men among this class, as among needle-grinders. Gem polishers and potters belong in this same category. Stonecutters and quarrymen are exposed to coarser kinds of mineral dust, but their work being conducted in the open air or in open sheds, they are by no means so prone to diseases of the lungs. Some stone is much dustier than others, and hence may cause more marked effects. Mica dust is exceedingly irritating, and, like the sharp particles of glass and steel, prepares indoor workers for the reception of the bacillus of tuberculosis. In the wall-paper industry, it is applied to obtain the effect of "frosting," and assists or is assisted in its action on the operatives by another very fine dust made of finely chopped or ground lambs' wool, which is applied to the pattern printed in size in much the same manner as obtains in bronzing cards. The workers are very prone to phthisis.

Vegetable dust is of very many varieties, which affect the system with varying degrees of intensity. Ordinary wood dust appears to be quite innocent of injurious action on the lungs of carpenters, whose employment is very largely out of doors, and of cabinet-makers, who, on the other hand, work in confinement. Grain threshers, millers, and many others exposed to vegetable dust present no great evidence that their callings are markedly inimical to health. Certain others, however, offer important and interesting facts, indicating that, either alone or as one of a group of influences, some of the vegetable dusts are as disastrous in their effects as some of the most irritant of those of metallic nature. Among the most unhealthy classes of workpeople are those engaged in cotton and linen factories. Cotton dust, or "flue," is very irritant to the upper air-passages, and causes dryness of the throat, followed by cough and expectoration. In some operations, a sized cotton thread containing kaolin is used, and then the air is laden also with this very irritating substance. Flax dust, or "ponce," is even more irritating than cotton.

In the linen factories of Belfast, which, according to G. H. Ferris,[1] employ 30,000 persons, five-sixths of whom are women, the deaths from phthisis and other respiratory diseases have been shown to outnumber those from all other diseases by about two to one. Among the women below thirty years of age, the death-rate from phthisis is three or four times as high as among women of the same ages engaged in other employments. In 1892, the phthisis death-rate reached the

[1] Journal of State Medicine, March, 1895.

enormous height of 41.1 per 10,000, against 14.6 for the whole of England and Wales, and 21.6 for all Ireland. Apart from the intrinsic danger of the occupation, however, it must be noted that the city itself, from the nature of the soil and climate, cannot be a healthy place, but, on the other hand, it must be said that overcrowding, which is so great a factor in the causation of the disease, cannot, in this instance, be charged with an unusual amount of influence, since in no other city in Great Britain and Ireland are there so many houses in proportion to the population.

Workers in tobacco are exposed not alone to irritating and poisonous dust, but to fumes as well. They are much subject to nasal and bronchial catarrhs and disorders of the digestive apparatus and nervous system. The women engaged are said to abort very commonly, on account of the death of the fœtus. Many assert that the occupation in itself is not an unhealthy one, and that it possesses certain advantages in that it renders the individual less susceptible to infective agents. As evidence of this, it is said that, during the great cholera epidemic at Hamburg, in 1892, there were but 8 cases of the disease, with 4 deaths, among the 5,000 cigarmakers there resident.

Animal dust is given off in the numerous industries in which wool, silk, feathers, fur, bristles, hair, horn, bone, shell, ivory, and other substances of animal origin are used. These substances are irritating to different extents, as would naturally be supposed from their very diverse character, some, as wool, feathers, and silk, resembling in action cotton and flax, and others, as shell, bone, and ivory, acting more like the mineral dusts. The operatives in woollen mills, appear, on the whole, to be rather less subject to phthisis than those engaged in the cotton and flax industries. Among the others of this class, those making brushes and buttons, especially pearl buttons, are regarded as taking greater risks than the rest. Most statistics of these industries are faulty and inconclusive.

4. Occupations Involving Exposure to Infective Matter in Dust.

This class includes those having to do with rags, wool, horsehair, hides, and other materials likely to be infected. The importance of rags as a vehicle for infection has been much overrated, but the danger is, nevertheless, a real one, as the experience of paper-makers has often demonstrated. The only method of insuring freedom from infection through the handling of rags is thorough disinfection, a process involving an expense, it is asserted, much disproportionate to the results achieved.

The most common disease connected with infected raw material is anthrax, or "wool-sorters' disease," the spread of which is often traced to horsehair, wool, and hides. Nichols[1] reported 26 cases of this disease as occurring in one curled hair factory in three years. Ravenel[2]

[1] Second Annual Report of the State Board of Health of Massachusetts, p. 86.
[2] Report and Papers of the American Public Health Association, Vol. 24, p. 302.

collected 12 cases occurring in men and 60 in cattle in three localities in Pennsylvania, during the summer and autumn of 1897. All of the men worked in tanneries, and all of the cattle were pastured in meadows watered by streams which received waste products from tanyards. The skins at fault came from China.

According to Dr. S. Leduc,[1] imported horsehair is the most dangerous material brought into France. The French market is supplied by South America, whence it is shipped in bales compressed by hydraulic pressure. Unpacking the bales and sorting the contents according to color are alike regarded as dangerous. After being sorted, the hair is beaten, and in this process much dust is caused. It is then carded and spun into ropes. The precautions to be taken include removal of dust by special blower apparatus, perfect cleanliness, and great watchfulness. Disinfection of the hair without impairing its commercial value or unduly increasing its cost is said to be impracticable.

Naturally, the danger of infection by the spores of anthrax on hides, hair, and the many kinds of wools coming from countries where the disease is common cannot in any individual case be foreseen. From ordinary sheep's wool, the danger is slight, and from native wools is practically non-existent. When, for any reason, danger is apprehended, workmen with sores, cuts, or abrasions on their hands, arms, faces, or necks, should not be employed, ventilation should be thorough, and all precautions should be taken to prevent dissemination of the dust.

5. **Occupations Involving the Inhalation of Offensive Gases and Vapors.**

This class of occupations includes a great variety of what are known as "offensive trades," having to do with organic matter largely of animal origin, such as tanning and currying, soap-making, glue-making, fertilizer-making, fat-rendering, bone-boiling, keeping animals, etc. While there can be no doubt that these offensive trades are a frequent source of nuisance to the community at large, evidence of injurious influence on the health of those actively engaged and of the population in the immediate vicinity of the works is decidedly slender. There can be no doubt of the disadvantage of having such establishments located in the midst of thickly settled communities, and hence their supervision constitutes a most important part of the duty of public authorities. The workmen are likely at first to suffer from nausea, vomiting, loss of appetite, and headache, but these evidences of disturbance disappear within a short time, and do not recur.

Contrary to general opinion, these occupations not only do not appear to shorten life, but from such facts as are presented by the mortality statistics of occupations, it may be inferred that they conduce to longevity, for, as a class, their average age at death is quite

[1] Public Health Reports, May 25, 1900, p. 1306.

high. It is hardly necessary to go into the details of the processes involved in the different callings.

6. Occupations Involving Exposure to Extremes of Heat.

Exposure to extreme heat is a concomitant of a number of other unsanitary influences which affect the health of the worker in a variety of occupations, which include those of engineers, stokers, cooks, bakers, miners, foundrymen, weavers, employees in rolling mills, wire mills, sugar refineries, glass factories, and others. The effects of great heat alone are exhaustion and thermic fever, and when to these are added those of vitiated air, dust, irritating fumes, and dampness, the consequences may be very grave. Sudden chilling of the body and prolonged exposure without intervals of rest are especially to be guarded against. The workmen of this class are commonly affected with catarrhal and rheumatic troubles, diseases of the kidneys, and skin eruptions.

7. Occupations Involving Exposure to Dampness.

Exposure to indoor dampness is usually only one of a number of debilitating influences, the effects of any one of which are not susceptible of correct measurement. Outdoor dampness is probably far less influential for evil; but continued exposure, coexistent with exhausting labor, is conducive to rheumatism and bronchial troubles. With ordinary care, however, those exposed to vicissitudes of weather and to wetness from other causes—drivers, boatmen, fishermen, and trench diggers, for example—enjoy good health and are, as a class, long lived.

8. Occupations Involving Exposure to Abnormal Atmospheric Pressure.

The principal calling of this group is that of caisson workers, who suffer from what is known as the caisson disease, the pathology of which is by no means clear. A caisson may be defined as a large inverted water-tight box in which work is performed below the water-level, as in the laying of foundations for the piers of bridges. It is, in fact, a diving bell on a large scale. It is provided at the top with a shaft for ingress and egress, communicating with which and with the interior is a chamber with two sets of doors, known as an air-lock. Placed in position and heavily weighted with masonry, it sinks into the mud beneath. The air in its interior is compressed by the action of the surrounding water, and the thereby diminished air space is restored by downward displacement of water through the agency of powerful air pumps. The deeper the caisson sinks, the greater, of course, the atmospheric pressure within. As the work of excavation progresses, the apparatus sinks deeper and deeper, being assisted in its downward

movement by the weight of the superimposed masonry; and when the proper geological formation is reached, the interior is filled with concrete, which thus forms the solid foundation, and the box is left there. In entering the caisson, the workman goes first into the air-lock and closes the door. The pressure in this compartment is then gradually equalized with that of the caisson chamber by means of an inlet pipe controlled by a valve, after which he opens the inner door and, entering the chamber, closes it again. In emerging, the process is reversed: the pressure in the air-lock being raised, he enters and closes the door; by means of another valve, the pressure is lowered gradually to normal, and then the outer door is opened. The operations of locking in and out must be conducted gradually. In locking out, the rule is to allow at least one minute for each 6 pounds of pressure within the chamber. Attention must be paid also to the lowering of temperature which accompanies the expansion of the air within the lock.

The symptoms of the peculiar disturbance do not, as a rule, appear until the pressure equals 20 pounds, and some time, measured in minutes or even hours, after emerging. In some cases in which cerebral and spinal symptoms are severe from the beginning, death occurs within a short time. The symptoms include headache, pain in the ears, rapid pulse, sweating, severe pains in the legs, back, and epigastrium, and, later, paralysis of the motor nerves, generally of the legs, sometimes of the arms, and not infrequently of the bladder and rectum. The motor nerves are in some instances involved before the sensory disturbances appear. The epigastric pain is accompanied sometimes by vomiting, more or less severe in character. Mild cases of the disease last from a few hours to a week or longer; but, whether mild or severe, complete recovery is the rule. Where electric lighting is not employed, irritation of the bronchial mucous membrane, cough and expectoration, due to soot, are not uncommon.

The cause of the main symptoms has been the subject of considerable speculation, and whether it is an excess of oxygen in the tissues, which seems improbable, or congestion of the central nervous system, or some other condition, appears to be incapable of elucidation. The use of intoxicants appears to be a predisposing influence; hence, drinking-men should not be employed. Thin men are much less susceptible than the stout and full-blooded. Work should never be performed on an empty stomach, and periods of absolute rest should be frequent when the pressure is unusually high.

Submarine divers are subject in a lesser degree to the same train of symptoms.

9. Occupations Involving Constrained Attitude.

These include a wide variety of trades leading to various deformities, the most important of which is constriction of the chest. Vitiated air is a common coexistent condition, and phthisis is a frequent cause of death.

10. Occupations Involving Overexercise of Parts of the Body.

The occupations of this class bring about a variety of deformities and of fatigue neuroses characterized by disturbance of the functional activity of groups of muscles trained by practice in highly specialized coördinated movements. These include such conditions as the cramps of writers, telegraphers, pianists, violinists, engravers, seamstresses, and others, and localized paralyses and tremors. The pathology of these conditions is very obscure; but in certain of the cases, especially those in which the larynx is overexercised, the element of hysteria enters to a considerable extent. These abnormal conditions are of far less hygienic importance than any that have been considered, and are of interest chiefly to the specialist.

11. Occupations Involving Sedentary Life.

Certain callings are commonly set down as *sedentary* occupations; but, strictly speaking, this class is closely interwoven with several of those already mentioned. For instance, a very large number of indoor occupations, carried on, perhaps, under conditions peculiar to themselves, are at the same time sedentary in their nature.

The abnormal conditions brought about by sedentary life are those induced by a lack of general exercise of the body. This brings about a general sluggishness of the functions, which is ordinarily most marked in those of the abdominal organs and heart. The consequences of too close confinement and lack of exercise are too well known to need detailed mention. Ordinarily, they can be expressed by the term "general debility." There is no particular reason why sedentary occupations should injure health, and it will be found in almost all instances of impaired function that the sedentary habit is not peculiar to the individual while at work, but during both work and leisure hours. The sedentary worker has the matter of prophylaxis in his own hands, and should take a reasonable amount of exercise daily, preferably in the open air. It is common to include brain-workers in this class, and to attribute to the sedentary side of their lives the consequences of overexertion of the mind. It must be remembered that activity of the mind has no shortening influence on life; but abuse of the mental powers, and especially mental worry, conduce to headache, insomnia, and general breaking down of the nervous system and of the general health.

PROPHYLAXIS IN GENERAL.

In what has gone before, it will be noticed that the disastrous effects attributed to occupations are in very large part due to non-observance of the principles of general hygiene, and chiefly to inattention to that most important sanitary measure, perfect ventilation. It will have been noted that in Groups 1, 2, 3, 4, 5, and 6, the conditions which bring

about impairment of health may be reduced very largely by a constant supply of fresh air. With proper attention to this matter and improvement in the home and home influences, greater attention to the character and preparation of food, and a more general observance of the beneficial influence of active outdoor exercise, no very great differences would be noted in the health of the various classes of workpeople, and the expression *occupation diseases* would lose whatever significance it now has.

Employment of Women and Children.

In view of the dangers and conditions incident to a great variety of occupations directly or indirectly inimical to health, it is of the utmost importance to protect the health of women and children by restricting them in the daily number of hours which they may give, and prohibiting their employment in distinctly dangerous surroundings, for women and children are more delicately organized and less resistant to weakening influences. Particularly should women be protected during the child-bearing age, so that they may be insured, so far as is possible, a healthy progeny. It hardly needs to be said that children should be protected most carefully during the period of their full development, in order that they may come to maturity in a fit condition to take on the responsibilities of the family.

Inattention to the very great importance of conserving the health of women and children is bound sooner or later to result in degeneration, and this fact has received the attention of the law-making bodies of all, or nearly all, civilized countries. In this country, it is constitutionally a matter for legislation by individual States, in many of which not only is their physical welfare protected, but the moral aspects of trades as well receive due attention.

By legal enactment, the employment of women in certain kinds of work is prohibited absolutely, and in many others is restricted as to number of hours according to the nature of the work. The very great value of most of the legislation regulating labor by children and women is too clear to need demonstration.

CHAPTER XIV.

VITAL STATISTICS.

The science of vital statistics comprises the analysis and synthesis of facts concerning the life-history of populations. It points out where and to what extent disease and death are on the increase, and suggests, therefore, the inauguration of combative sanitary effort, the efficiency of which it enables us to measure. It furnishes the basis for the study of all the various social problems which affect increase and diminution in numbers.

It is axiomatic that the facts employed must be numerous and accurately stated and classified, in order that the information supplied therefrom shall be trustworthy and of value. These facts comprise those which are yielded by the census, as numbers, age, sex, color, occupation, and conjugal relations, and those reported to and recorded by local and central authorities concerning infectious diseases, marriages, births, and deaths.

The study of these facts and their correct interpretation are by no means simple. In census years, it is not difficult to obtain practically accurate information of the size of the population, and the ratios of births, marriages, and deaths, and at all times to know the degree of prevalence of notifiable disease; but the intelligent interpretation of these facts is often, if not usually, a most complex problem. In the hands of those who understand the fallacies, the numerous sources of error, the corrections to be applied, and the comparative values, statistics can be made to yield knowledge of immense value to sanitary science; but in the hands of the unskilled or unscrupulous, they may be more productive of harm than absolute ignorance, for it is better not to know at all than to be misinformed.

It is well known that it is often possible apparently to prove two direct opposites with the same statistics, the fallacies being unobserved, and to this fact is due the low estimate in which all statistical studies are held by those incapable of distinguishing the false from the true. Statistics may be made to lie while they appear to tell the truth, and they have been raised to superlative rank, therefore, among falsifiers of all degrees.

As has been said, the interpretation of statistics is no simple matter. It requires, in fact, a mind not only naturally logical, but trained in drawing scientific inferences, in the recognition and avoidance of the influence of fallacy, and in the correct estimation of the value of different factors and disturbing influences. But even with several such minds working on the same mass of material, decided differences may

be found in their respective conclusions, some apparently small fact being overlooked by one or being credited with undue importance by another. Therefore, in publishing facts and inferences, it is well to give as much as possible of details, and to bring out clearly the thread of the reasoning leading to the final conclusions, for then, other analysts may, by pointing out debatable issues, assist in deducing the absolute truth.

The Census.—The very foundation of vital statistics is a knowledge of the size of the population and of the ages of the units of which it is composed. In census years this may be regarded as substantially accurate; but in the intervening years it is necessary to make estimates based on past and present indications, which may lead to wide variations from the truth, not susceptible of correction until the next enumeration. The census is taken in all civilized countries at stated intervals, usually of five or ten years. In France and in Germany, it is taken every five years; in this country and in Great Britain, every ten years. In this country, many of the individual States have an independent enumeration in the middle of the intercensal period, so that the census is virtually quinquennial. The census gives the population of each community, and also important facts as to age distribution, sex distribution, race, occupations, and civil state.

From the very nature of the work, dealing in a very short time with vast numbers of individual sources of information, no census can be absolutely accurate, but under present methods the results obtained may be regarded as being as nearly accurate as possible. It is probable that, in a large degree, the errors counterbalance one another, but how far, can be only a matter of conjecture.

The sources of error in census-taking are intentional frauds and negligence on the part of the enumerators, ignorance and wilful misstatement on the part of those interrogated, absence of residents when called upon, and inclusion of transient visitors. In 1890, it is well known, in certain cities gross frauds were practised in "padding" the returns so as to increase the fees due the individual enumerators concerned. In one case, a hotel register, running back seven years, is known to have served as an aid in the manufacture of population returned. During the same census, many complaints were made that whole streets and districts were omitted, the inference being that the enumerators either did not regard the work as sufficiently remunerative, or made up their reports regardless of the facts, and without the disagreeable necessity of going from house to house for information only slowly obtained.

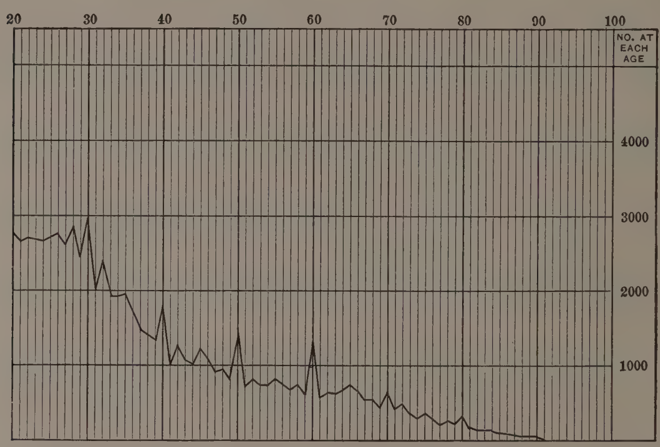
Ignorance on the part of the person questioned is doubtless a more fruitful source of error than intentional misstatement. Many persons do not know their age, and give, therefore, only a guess, which is most commonly expressed in multiples of five and ten, more especially the latter. This tendency appears, in general, only after the twenty-fifth year, and is shown graphically by means of the accompanying diagram (Fig. 108) by Mr. R. H. Hooker, taken from Newsholme's Vital Statistics. Again, many data concerning the occupants of a house are

given by persons not qualified to know; thus, the returns for a whole family may be based upon the statement of a servant not long in the place.

Intentional misstatement is most common with regard to age and occupation, many wishing to appear younger, others older, than they really are, and many being reluctant to state correctly the occupations of themselves and of members of their households, preferring, perhaps, to record others more "genteel" or important. Other wilful misstatements are due very commonly to that over-development of the sense of humor that disposes its unfortunate possessor to regard extravagant lying as the acme of wit.

The intentional misstatement of age is more commonly a fault of women than of men. Women are prone to understate their age after

FIG. 108.



Number of persons in Tasmania living at each year of age, according to the census schedule, showing the tendency to cluster at round decennial periods.

passing twenty-five; with men, the tendency is to add rather than subtract. After twenty-five, many women become sensitive, and give their ages as under that age, and do not progress for several years. This is shown statistically by the British census returns, from which it appears that the girls of 10 to 15 years of one census, who become women of 20 to 25 years of the next census, reach these latter age periods without suffering any loss in number through death and emigration; but, on the contrary, with an augmentation, while the women of 20 to 25 years, who become 30 to 35 years old at the next census, show a very great diminution in number.

Thus, as shown by Dr. Farr, the Registrar-General, in 1841, the number of girls of 10 to 15 years was 1,003,119, and in 1851, the number of women of 20 to 25 years was 1,030,456, or 27,337 more, while the women of 20 to 25 years in 1841 numbered 973,696 and yielded in 1851 only 768,711—a loss of 204,985. It is inconceivable

that the losses among the younger group, due to death and emigration, should have been more than offset by immigration to the extent of 27,337, and that the same influence should have failed to the extent of 204,985 to do the same thing for those of the later age periods. This discrepancy is said to be capable of demonstration by comparison of the returns of any two consecutive subsequent enumerations. Children's ages are very commonly overstated in the earliest years; then, as the limit of age for free transportation in public conveyances is passed, they are understated as long as possible. Finally, when the statutory minimum of age is the only bar to the utilization of children in the various trades, the years held back are restored with some additions.

Estimated Population.—In intercensal years, it is necessary to estimate as nearly as possible the growth or decline of a population, making use of such factors as can be obtained by comparison of the two preceding enumerations and from other observed influences. This is done very commonly by dividing the difference between the figures of the two by the number of years of the interval, thus obtaining the yearly increase or diminution, and reducing it to a percentage which is assumed to be the rule obtaining until the next census. This, of course, is merely a guess which may be near or very wide of the truth, since very many influences may be in operation to bring about conditions actually very different. But one must work with the best data available and eliminate as much of error as possible; hence the ratio of increase or diminution is assumed to hold until the next census, and in the meantime errors must be diminished as much as possible.

One of the first errors into which one falls is in assuming a fixed ratio, based upon the above-mentioned method of calculation. Let it be assumed, for example, that the annual increase in the population of a city of 100,000 inhabitants, determined by a comparison of the two preceding enumerations, is 2 per cent.; if we reckon that in 5 years' time the population will have increased 5 times 2 per cent., that is to say, from 100,000 to 110,000, we fall at once into error, for the increase proceeds not by simple but by compound interest, since in reckoning by simple interest no allowance is made for the augmentation of capital, so to speak, due to the annual increase in the number of persons arriving at the nubile period.

The method generally adopted is, therefore, based on the assumption that population increases in geometrical rather than arithmetical progression, and the formula employed is $P' = P(1 + r)^n$, in which P' represents the estimated population, P the population according to the last census, r the annual rate of increase per unit of population, ascertained by comparison of two successive enumerations, and n the number of the intercensal year in question. On the basis of a 2 per cent. annual increase, the population at the end of the first year would be 102,000; at the end of the second, it would be 102,000 plus 2 per cent., or 104,040; at the end of the third, 106,121; at the end of the

fourth 108,243; and at the end of the fifth, 110,408, or an increase of 408 over the original estimate.

As an illustration of the manner of applying this formula in the estimation of the population at the expiration of the fifth intercensal year, in this instance of an original population of 100,000 increasing at the rate of 2 per cent., the following may serve: The formula is $P' = 100{,}000 \times (1 + 0.02)^5$; $(1 + 0.02)^5 = 1.10408$. $100{,}000 \times 1.10408 = 110{,}408 = P'$ as given above. Much time is saved in the calculation by recourse to logarithms. For a proper estimation of the population at any particular period in the year on this basis, due allowance should be made for the fraction of the uncompleted year.

Population is sometimes estimated by using as a factor the average number of persons per habitation according to the preceding census returns, and multiplying this by the number of houses found to be occupied at the time. Sometimes, also, the number of registered voters is used as a basis of calculation, and again the birth-rate, and again the number of children in attendance at the several schools. These methods, however, are very faulty, and often even quite valueless.

Whatever the method adopted, and notwithstanding the calculations of the amount of influence exerted by emigration, immigration, unusual prevalence of or freedom from infective diseases and other factors, estimation of population is very frequently wide of the truth. Within recent years, for example, the most careful estimate of the population of London by the Registrar-General was found by the census returns to be no less than a quarter of a million in excess of the truth. With errors in estimation come necessarily errors in all the ratios of births, marriages, and deaths, and these must, therefore, undergo correction at the proper time.

Increase of Population.—The growth in population due to excess of births over deaths is known as the *natural increase*. That which is due to excess of births plus immigration over deaths plus emigration, is known as the *actual increase*. Fluctuations in natural increase are caused by changes in mortality- and birth-rates; thus, a decline may be due to a diminution in the number of births, or to an increase in the number of deaths, or, more markedly, to both. Fluctuations in actual increase are caused by the same influences plus those of immigration and emigration. Growth may, therefore, be slow or fast, and steady or varied and spasmodic, according to ever-possible changing conditions, governed largely by commercial prosperity or depression. Decline in population may be due to excess of deaths over births, but is commonly the consequence of emigration.

Population Constitution.—What is known as the constitution of a population shows the relative proportions of males and females and of persons of different age periods. These facts are obtained only from the census returns, and are commonly accepted as holding good until the next census gives different figures. In cities and large towns, the proportion of females is generally considerably higher than that of males; while in country districts the reverse is true or the excess is

slight. This is explained in several ways: In the first place, women are, in general, longer lived than men; in the second, men are more prone than women to return, when advanced in years, to country districts from which they originally sprang; and again, under the conditions obtaining in crowded communities, men wear out more rapidly than women. In the population at large, males are more numerous than females.

Age distribution has a very important bearing on the death-rate, since, as is well known, the highest death-rates, so far as age is concerned, occur always in the earlier age periods. Therefore, the preponderance of individuals of one and another age period has a very great influence in demonstrating apparent differences in salubrity of different localities, when the actual sanitary conditions are identical. With such agreement in sanitary conditions, a community which includes a much larger proportion of young children will show a larger death-rate and a smaller marriage-rate than another in which the population is made up more largely of young adults. In consequence, it is necessary, in instituting comparisons between two localities, to take into account (and make corrections therefor) the differences in age distribution, and to reduce the respective populations to a common standard.

Registrars' Returns.—Returns concerning births, marriages, deaths and causes thereof, and cases of infective diseases, are made to local authorities, such as boards of health, and city or town clerks or registrars. In conjunction with census returns or estimates of population, they reveal the sanitary and sociological conditions obtaining from week to week, month to month, and year to year, in any community in which they are made. Through them we are enabled to watch the death-rate from all causes and from any one cause, the amount of preventable disease, the probable fluctuations in populations, and other facts of interest concerning communities and groups thereof. They convey information as to sanitary conditions, and suggest wherein improvement in various directions is possible.

The individual facts must, of course, be accurately observed and stated. This is particularly true of causes of death and distribution of infective diseases. The importance of proper groupings is well shown by the worthlessness of the lax returns not infrequently observed. For example, it is not unusual, especially in the older tables, to find "dropsy" standing side by side with "heart disease," "kidney disease," Bright's disease, and other general or vague terms.

The value of the aggregate facts depends very largely upon the length of time during which they have been gathered, since only with the lapse of time can comparisons be instituted and the influence of temporary conditions eliminated or minimized. They must be sufficiently numerous to yield correct averages, for the larger the number of facts, the smaller the fluctuations caused by individual units; and, conversely, the smaller the number, the greater the influence of single units, and the greater the chance of error; or, more definitely stated, accuracy increases as the square root of the number of units. Thus,

400 units will yield but half the error of 100, and 900 will yield but a third. In no way, perhaps, can the great influence of individual components of a small aggregate and the small influence of the unit when the aggregate progressively increases be better illustrated than by the daily fluctuations in the comparative standing of a number of athletic organizations, such as ball clubs and bowling clubs, in competition among themselves for a prize or championship. In the beginning, single events may cause entire rearrangement, and the fluctuations are wide and the curves most irregular; then, as the number of events increases, the fluctuations are less abrupt and the changes in the curves are gradual.

In order that statistics may be useful, they must admit of comparison with similar figures obtained in other years and also at other places. But correct deductions can be drawn only when the conditions are at least apparently the same or when there is but one essential difference. One may not, for example, compare the death-rate of New York for the winter of 1898 with that of Detroit for the summer of 1875, and expect to obtain thereby information of value. In order to measure the full influence of any one important condition, the other conditions must be in agreement, or it must be possible to make correct allowance for any degree of divergence.

Again one must not ignore the effect of temporary local conditions, such, for example, as an accident in a small community whereby a number of persons are killed at once and others die later from the effects of their injuries. The death-rate of that town for that year would be abnormally high, and the sanitary condition of the place might be made by figures to appear much inferior to that of an adjoining one where sickness and death from preventable diseases are much higher all the time.

Marriage-rates.—Statistics as to marriage vary considerably from year to year, according to various circumstances, and especially with changing conditions in the prosperity of the general population. The rate is commonly greater in cities and towns than in country districts, not that country-bred people are less inclined to marry, but because large numbers of them are attracted to populous centers after arriving at the wage-earning age, and there they marry.

The marriage-rate is usually expressed as so many per 1,000 of population; but this is commonly open to objection, in that it may convey false impressions concerning inclination or disinclination to assume the new responsibilities, and also concerning the communal prosperity. Here, the importance of the population constitution as to age periods and sex is very clear, for in a community made up largely of old persons, young children, and domestic servants from without, the number of marriages occurring among the marriageable element might be very considerable, and yet the rate per 1,000 of population would be low. Therefore, a more instructive method of expression would be a statement of the rate obtaining among those of marriageable age. Again, the number per 1,000 of population does not admit of proper compari-

son of different communities in this particular, unless their population constitution is substantially the same.

Fluctuations in marriage-rates are due to other causes than commercial prosperity and depression. It has been observed, for example, that a condition of war diminishes the rate by withdrawing from the marriageable ranks of wage-earners large numbers of able-bodied active men. With return of peace and its attendant release of the troops to civil life, the rate is augmented. Thus, during 1870, when France and Germany were at war, the marriage-rates sank respectively to 12.1 and 14.8; two years later (1872) they advanced to 19.5 and 20.7. Age constitution, too, has necessarily an important influence in causing fluctuations. Thus, in a community largely made up of youths and maidens, the time comes when an unusual amount of marriageable material becomes available, and the rate at once advances.

A period of unusual increase in the rate, from whatever cause, is commonly followed by a corresponding decline, just as business prosperity and depression are marked by regular waves; but the general trend is unmistakably toward a diminution. For nearly thirty years, a very gradual decline has obtained in nearly all highly civilized countries.

That more women marry than men, sounds paradoxical, but it is, nevertheless, true; for men are more prone than women to second and third marriages, and statistics show that the tendency of widowers to marry spinsters is much more marked than that of bachelors to marry widows.

The age at which marriage occurs has a very important bearing on the natural increase of population, since whether a woman marries early or late in the child-bearing period, determines, other conditions being the same, the extent of fruitfulness and, more particularly, the interval between successive generations. Statistics indicate that, among the native-born of this country, particularly in those parts longest settled, and in Great Britain and other countries in which the highest degree of civilization has been reached, the average age at marriage is steadily increasing. This has been attributed to an intelligent selfishness, tending to defer the assumption of responsibility for the maintenance of others, thus insuring an unrestricted enjoyment of the fruits of labor; and to the wider opportunities for profitable employment of women, with consequent lessened dependence upon marriage as a means of support.

Birth-rates.—Statistics as to births are expressed in the same manner as those concerning marriage; namely, as so many per 1000 of population. This ratio is known as the *crude birth-rate*, and conveys no information concerning the proportion of women of the child-bearing age who have added to the population. Here, again, a more accurate and instructive method of expression might be based upon a comparison of the number of legitimate births with the number of married women below forty-five years of age, and of the number of illegitimate births with the number of single women of the same limit of age. Under

any system, still-births are not included in either the births or deaths, although they are certified.

Birth-rates naturally vary very greatly in different communities, the same as marriage-rates, and for the same reasons. Ordinarily, they are higher in cities than in the country, and during and immediately following periods of prosperity than during times of depression. A higher rate is to be expected of a manufacturing and commercial center than of a purely residential town, where a large number of unmarried domestics, employed by the well-to-do and rich, swell the population and lower the rates of both marriages and births in the manner already mentioned. In the latter case, the married inhabitants may be unusually prolific, and the birth-rate, expressed per 1000 of married women below forty-five, would be very high; yet, the crude birth-rate would be low. So, in comparing two communities in respect to births, accuracy demands that they shall be reduced to a common basis.

The higher birth-rate in cities and large towns is due to the greater proportion of women of child-bearing age, the higher marriage-rate, and the earlier marriage age that there obtain among people of the lower classes.

Since the proportion of deaths in the earliest years of childhood is very high, it follows that a high birth-rate is always associated with a high death-rate; but at the same time, a high birth-rate implies a large proportion of married persons in the full vigor of life at that age period which is associated with a low rate of mortality, and thus the influence on the death-rate is more or less corrected. A continued high birth-rate necessarily implies a large proportion of growing children who, year by year, swell the ranks of the reproductive.

A low birth-rate, by causing a relative increase in the proportion of persons of the age periods of low mortality, may bring about a low death-rate; but if it continues long enough to bring the population to a high average age, it will be succeeded by a rapid increase in the death-rate due to diseases of advancing years.

The birth-rates of many countries, like the marriage-rates, have for some years shown a steady decline. This is due somewhat to the increasing average age at marriage, which reduces the period of reproduction, but largely to artificial restrictions and economic considerations. The great decline in the birth-rate of France has attracted widespread attention, and has become the subject of grave concern to the authorities and other thinking people of that country. A hundred years ago, more than a quarter of the population of what are known as the Great Powers was French; to-day, notwithstanding the marked disinclination of that people to emigrate and seek new homes, the proportion has fallen to about one-eighth. In 1891, according to census returns, of every hundred families, 22 had but 2 children, and 24, but 1 child, apiece. The decline in births is not due to poverty, for it is among the poorest there, as elsewhere, that the largest families are raised. The same influences appear to have been in operation for some years in England and Wales, where, since 1876, when the birth-rate was 36.3,

it fell progressively in twenty years to 29.7, and showed in the last years of the century a more striking decrease than in any other country of Europe.

In our own country, among the descendants of the original colonists and earlier immigrants, the same decline is most evident. Whereas in colonial times and in the earlier years of national independence, families of a dozen, fifteen, and more were exceedingly common; nowadays, one of six or eight becomes a subject for comment, surprise, and even ridicule. The large families of to-day are mainly those of the more recently arrived immigrants and of their first generation. In Massachusetts, the statistics for 1898 show that the greatest proportion of the number of births belongs to the foreign-born, the children of native parentage on both sides representing 32.36, those of mixed parentage, 19.42, and those of foreign-born parentage, 48.22 per cent. of the total births. The crude birth-rate was 27.37.

Death-rates.—Death-rates are calculated in the same way and expressed in the same terms as birth- and marriage-rates, that is, by multiplying the number reported by 1000 and dividing the product by the population, or by dividing the reported number by the number of thousands of population, the result in either case being the rate per 1000 of population. This is known as the general, gross, or crude death-rate, and is affected by so many factors that, without careful study and due allowance for disturbing influences, it may prove to be a very faulty index of the health of the people and of the sanitary condition of the place. When used as a basis for comparison of different places, the death-rates must first be corrected by making careful allowances for differences in age, sex, and race distribution, and for abnormal influences.

Influence of Sex.—Sex exerts a decided influence, since, in general, females live longer than males and their mortality is lower at all age periods, excepting from the tenth to the twentieth year. So, of two places equal in sanitary and all other conditions excepting sex constitution, the one with the greater proportion of females will have the lower death-rate. Except in newly settled places, there is, as a rule, a preponderance of females over males, although everywhere the births of males exceed in number those of females, the preponderance being the result of the higher mortality that obtains among males, except at the age periods above mentioned.

Influence of Age.—The influence of age distribution is far greater than that of sex, since, for example, the mortality per 1000 of children under 5 years of age is more than ten times that of persons between 5 and 25, and more than six times that of adults between 25 and 45. Thus it may be seen that the greater the proportion of population belonging to the earliest and latest periods of life, the higher will be the death-rate. One would expect, for example, a higher mortality in a community made up largely of elderly people or young children than in one unusually rich in young adults, or, to reduce the

matter to its simplest terms, in a foundling asylum or retreat for the aged than in a college for young men.

Influence of Race.—To a certain extent, racial peculiarities have an influence on vitality, and especially on susceptibility to certain diseases. Thus, the negro is far less prone to some and far more susceptible to other morbid influences than the white. As between different peoples of the same race, the differences are not so wide. In those parts of this country where the negro population is considerable or preponderant, this influence can never be disregarded, and, indeed, it is commonly the practice to calculate separate rates for the whites and for the blacks. According to Hoffman,[1] the mortality of whites and blacks in ten southern cities, including Baltimore, Washington, Richmond, Memphis, Louisville, Atlanta, Savannah, Charleston, Mobile, and New Orleans, during the years 1890–94, was expressed as 20.1 and 32.6, respectively. This divergence, it is pointed out, would be still greater, if correction were made for age distribution.

The excess of negro mortality obtaining at all age periods is especially noticeable in the earlier ones. Thus, in 1890, in Washington and Baltimore, the death-rates of negro children under 5 and between 5 and 15 years of age were more than double those of white children of the same age periods; in the age periods from the fifteenth to the forty-fifth year, the rates for both races naturally diminish very much, but the ratio is nearly the same. After the forty-fifth year, the difference begins to be much less, but the excess is always with the negro.

As instances of the differences in white and black death-rates, the following are presented:

New Orleans . . .	December,	1899,	White, 23.49;	Colored, 28.59
	January,	1900,	" 28.28;	" 44.80
	March,	1900,	" 22.50;	" 39.60
Baltimore	November,	1899,	" 13.42;	" 22.30
	December,	1899,	" 15.00;	" 29.38
	January,	1900,	" 17.90;	" 30.60
	Whole year,	1900,	" 17.48;	" 33.42
Atlanta	Whole year,	1900,	" 11.59;	" 19.50
Augusta, Ga. . . .	" "	1899,	" 10.50;	" 31.00
Charleston	5 wks. ending Jan. 6,	1900,	" 15.70;	" 33.23
	4 " " Feb. 3,	1900,	" 12.60;	" 27.50
	2 " " Feb. 24,	1900,	" 19.81;	" 32.94

The difference between white and black mortality is believed to be due more largely to race degeneration than to sanitary conditions. In the North, the negro shows an excess of deaths over births, and holds his own only by influx of recruits from the South.

According to Dr. Seale Harris,[2] before the Civil War the negro death-rate in the South was less than that of the whites. For example, in Charleston, S. C., from 1822 to the beginning of the war the

[1] Race Traits and Tendencies of the American Negro. Publications of the American Economic Association, New York, 1896.

[2] The Future of the Negro from the Standpoint of the Southern Physician, American Medicine, Sept. 7, 1901.

average death-rate of the whites was 25.98, and of the blacks 24.05; but from 1865 to 1894, although the rate was but slightly higher in the case of the whites (26.77), it had nearly doubled (43.29) with the blacks.

From what has been said, it must be evident that crude death-rates cannot be relied upon as a basis of mortality comparison of two places, unless the respective populations are in substantial agreement in age, race, and sex constitution, nor for comparison of the conditions obtaining at the same place in different years, unless these factors are practically unchanged.

Other Influences.—Crude death-rates are influenced by errors in estimated population, by the presence of various kinds of public institutions, such as hospitals, state almshouses, and asylums for foundlings and the aged; by migratory movements; by density of population, and, as has been stated, by the birth-rate. An important source of error lies in the return of persons afflicted with incurable diseases to their old homes, where they die; their deaths are registered there, instead of at the places where the causes thereof had their origin or where the sanitary conditions were such as to favor susceptibility.

Influence of Density.—Death-rates, especially those of the very young, are much higher in crowded localities than where the population has plenty of room; and it is commonly accepted that, other things being equal, increased density means increased mortality. To a certain extent this is undoubtedly true, particularly where increased density means overcrowding; but it is not necessarily true of a large population spread out over a territory capable of accommodating twice as many people very comfortably. Thus, in Massachusetts, for example, where, in 1855, the population averaged 136 to the square mile, the general death-rate was about the same as obtained forty years later, when the average population per square mile had more than doubled, the slight difference being in favor of the later period. During the decennium just prior to the outbreak of the Civil War, the average rate was 18.25; during the period 1887–1897, it was about 19.50; and in 1898, it was but 17.55, which was the lowest annual rate for thirty-two years.

In densely populated, *overcrowded* localities, such as the slums of large cities, we find all the conditions which favor a high mortality; namely, poverty, immorality, ignorance, intemperance, unsanitary habitations, high birth-rate, carelessness, filth, and improper and insufficient food. In fact, the slums are, in very great measure, the cause of the differences observed in the death-rates of small and large communities. In country districts, small towns, large towns, and cities situated within the same district, where climatic and other natural conditions are essentially the same, it is commonly observed that the higher average rates obtain in the larger communities, and the lower in the smaller places, where slums are unknown; while the very highest occur in manufacturing centers, where the main population consists of mill operatives, who work by day under unsanitary conditions and pass their nights in crowded tenements. So, also, higher rates obtain in old manufacturing

places, in which a larger proportion of population of a weak and degenerated type is to be found, than in others more recently established.

Weekly Death-rates, etc.—The death-rate for any particular week is obtained by multiplying the number of deaths occurring during that period by 52.14 (the number of weeks in 365 days) and dividing the product by the number of thousands of population as estimated for the middle of the year.[1] The same method of reckoning may be employed for determining the rates for other fractions of a year, and for rates of birth, marriage, zymotic disease, and other matters of statistical interest. These weekly and other periodical rates are highly unreliable data upon which to base comparisons with those of other places and of other parts of a year, since seasonal influences and temporary conditions must not be ignored; their principal value is in comparing the rates obtaining at the same place at corresponding periods of different years.

In the same way, the weekly death-rate from any given cause, or the weekly number of cases of any particular notifiable disease, such as diphtheria, scarlet fever, or measles, may be determined.

Zymotic Death-rate.—The zymotic death-rate is the death-rate due to the seven principal so-called zymotic diseases; namely, smallpox, scarlet fever, measles, diphtheria, whooping-cough, typhoid fever, and diarrhœal diseases. It is expressed in terms per 1000 of population, like the gross death-rate. The rate for any disease may be similarly obtained and expressed.

Infantile Death-rate.—The infantile mortality is not expressed in terms per 1000 of the whole population, but as the number of deaths of children under one year of age to each 1000 births registered during the year. It is assumed that the efflux of living children whose births have been registered with the local authorities is counterbalanced by the influx of others whose births are registered elsewhere.

Infantile mortality is always high, owing to a variety of causes, and it is particularly high in slums and in manufacturing towns where women are largely employed in factories, and so are unable, even though so inclined, to give that personal attention to their offspring as is bestowed by mothers whose lives are purely domestic. In Massachusetts, for example, the infantile death-rate averaged, in the decade 1881–1890, 174.9 in the cities and 129.5 in the country, and the extremes for the cities were 239.7, at Fall River, preëminently a "mill town," with all that the term implies, and 111.9 at Newton, where manufacturing is at a minimum and overcrowding practically unknown. Lowell and Lawrence, also "mill towns," showed respectively 222.5 and 213.9, while Boston, commercial, manufacturing, and residential, showed 188.2.

[1] Many statisticians employ the factor 52.17747, the number of weeks in the solar year of 365 days, 5 hours, 48 minutes, and 46 seconds. This exaggeration of exactness in small things seems all the more absurd when we consider that the estimation of population at the middle of the year is nothing more than a fairly reasonable guess, and often proves to be wide of the truth.

In the three cities with the highest rates, Fall River, Lowell, and Lawrence, the population is largely French-Canadian operatives of cotton and woollen mills, housed in crowded tenements. The so-called "shoe towns," Haverhill, Marlboro, Brockton, and Lynn, have a very different kind of population, much better paid and not inclined to a tenement-house life, and show respectively 157.1, 154.6, 146.9, and 140.7, all of which rates are below that of the State at large, 160.4.[1] Similarly, in England and Wales, where in 1894 the rate was 137, and in 1896, 147.5, Preston, which can claim one of the blackest records in all respects among mill towns, showed, in the former year, 229, and in the latter, 262, while in London the rate was but 159.

The chief factors in the causation of high infant mortality are premature births, heredity, intemperance, early marriages, neglect, carelessness, ignorance, improper food, unsanitary surroundings, industrial conditions, illegitimacy, and, perhaps, infant life insurance. The immediate causes are chiefly inanition, diarrhœal diseases, measles, whooping-cough, and other infective diseases, and violence. The influence of premature birth, heredity, neglect, carelessness, ignorance, and unsanitary surroundings needs no elucidation. Industrial conditions figure largely in the neglect of infants, since mothers in employment return as soon as possible after confinement to their work, and entrust their offspring to the care of older children and others, by whom they are improperly fed and looked after. During pregnancy, also, the woman remains at work up to the last possible moment, so that her absence is limited to that period during which she is absolutely incapacitated.

The age of the parents has much influence on the vitality of infants, those of mothers under 20 dying off appreciably faster than those of others between 20 and 30. Between 30 and 35, the vitality of the offspring is still greater; but after this age period it begins to decline. The first children of very young fathers also are, as a general rule, weaker than those begotten later. To this influence of the parents' age, conjoined with that of ignorance and inexperience, may be attributed the excessive mortality which obtains among the first-born.

Illegitimacy has a very great influence on the chance of survival to even the early period of childhood, for the infant is in an unfavorable position as regards care and home surroundings from the beginning. Abandoned by the mother to the care of whomsoever may be willing to accept the charge, or "farmed out" among persons whose interest in its welfare is wholly financial and subject to immediate decline on the cessation or tardiness of payments, it has even less chance, perhaps, than when kept at home, an unwelcome addition both to the family circle and to the expense account.

Infant insurance is generally believed to be an influence in diminishing the amount of care and solicitude for the health of the very young,

[1] These figures are taken from a communication from Dr. S. W. Abbott, Secretary of the State Board of Health of Massachusetts, on "Infant Mortality in Massachusetts." Journal of the Massachusetts Association of Boards of Health, December, 1898, p. 134.

and, therefore, has been the subject of considerable legislation, by which the maximum amount of the policy is kept at a low figure, as, for instance, the actual expense of burial. Whether insurance has more than an insignificant bearing, cannot be determined by trustworthy statistics.

Beyond doubt, the most fruitful single cause of high infant mortality is improper feeding, due partly to the necessity of supplying an artificial substitute for breast milk and partly to ignorance. The breast-fed infant, carelessly looked after, has a far better chance than the bottle-fed more carefully tended. The former receives its natural food at a uniform temperature and practically sterile; the latter is fed upon another kind of milk, differently constituted and of a different degree of digestibility, which, under the best of circumstances, is comparatively rich in ordinary bacteria, and is administered at different temperatures, sometimes very hot, sometimes cold. With lack of care, the danger is increased, for the milk may be stale and dirty, and act as the vehicle for the exciting cause of cholera infantum, which is responsible to a greater extent than any other morbid condition for the deaths in mill towns of infants whose mothers are employed in the various industries. Besides dirty and stale cows' milk, a variety of cereal and sugar substitutes are provided, which may or may not be digestible and nutritious.

Ignorance of what is proper for introduction into an infant's stomach is responsible for much infantile mortality, even when breast-feeding is followed. Who has not seen fond, but ignorant, mothers, in public conveyances, keeping their infants quiet with bananas, seed cakes, cookies, and other food materials unsuited to a digestive system which can have difficulty enough with milk alone? It seems unlikely that such practices are restricted to the time spent in travel, when consideration for the comfort of strangers suggests the avoidance of fretting and crying.

Death-rates of children under five years of age are expressed in the same terms as infantile mortality, that is to say, as the proportion of deaths per 1000 children of that age period.

High and Low Death-rates.—In the absence of any unusual general unsanitary condition or of unusual prevalence of epidemic diseases, an abrupt rise in, or a very high, death-rate is not infrequently only apparent, being based upon an underestimated population. A very low death-rate is always open to suspicion, although sometimes, as in newly settled communities with a very high proportion of young male adults, for a limited term of years, it is perfectly possible and natural. A rate of 15 per 1000, for example, in large cities, is so low as to suggest that the population has been very much overestimated. Within recent years, the authorities of a rapidly growing Western city noted with great pride the gigantic strides in the estimated population, and were naturally much elated to find that the death-rate based thereon entitled the city to a position in the first rank of the cities, large and small, of the whole world. The census of 1900 dispelled the illusion,

for the population had been grossly exaggerated, and the actual death-rate was comparatively high.

Death-rates as low as 10 and 12 are sometimes noted. A continued rate of 10 in a stationary population would mean that the inhabitants would average 100 years of age at death; one of 12 would mean an average age of over 83; one of 15 would mean an average of nearly 67.

As examples of high and low death-rates, the following for the same quarter of the same year (1897) may be cited:

High.		Low.	
Dublin	39.9	Frankfort on the Main	15.6
Moscow	36.9	The Hague	16.2
Bucharest	33.2	Berlin	17.0
Belfast	31.3	Christiania	17.7
St. Petersburg	31.0	Amsterdam	17.8

The influence of improved sanitation in the lowering of the mortality of any given place cannot be disputed, but in attributing the whole or even the greater part of the difference in the rates of any two places or of the same place in different years, one should be careful not to ignore factors, already mentioned, that exert influences beyond the control of sanitary authorities. Permanent decline in mortality-rate is a matter of slow growth, and is the combined result of sanitary effort and mitigation of the occupational and social conditions tending to lower vitality. In Elizabethan times, the death-rate of London was about 40; at the beginning of the reign of Victoria, it was 24, and at the end of the century, about 19.

Correction of Death-rates.—The impossibility of making a fair comparison of the death-rates at different places without taking into consideration the constitution of the respective populations as to age, sex, and race, has been sufficiently pointed out; and since two places absolutely alike with regard to occupational influences, wealth, density of population, climate, soil, water-supply, sanitary administration, and general sanitary condition, but discrepant as regards the distribution of the sexes, age periods, and race, may show very different death-rates, perhaps magnifying the salubrity of the one and exaggerating the unhealthiness of the other, it becomes necessary to have some method of bringing them to a common basis. In the matter of race influence, the best plan is to separate the statistics absolutely, having one set for the white and another for the colored population, and to compare white with white and negro with negro.

The method commonly recommended for correcting according to sex and age is the one in use in the office of the Registrar-General for England and Wales; this may briefly be described as follows:

The mean annual death-rate of the country for each sex at each of the eleven age periods, namely, below 5, 5–10, 10–15, 15–20, 20–25, 25–35, 35–45, 45–55, 55–65, 65–75, and 75 and upward, during the last preceding ten years, is obtained and multiplied by the number of those of each sex at each corresponding age period in the territory under consideration, according to the returns of the last preceding

census. Each product thus obtained, divided by 1,000, gives the calculated number of deaths for the respective sex and age periods. These 22 results, added together, represent the calculated number of deaths for the place in question in one year. The total calculated number of deaths, divided by the number of thousands of population or multiplied by 1,000 and divided by the population, gives the *standard death-rate.*

The next step is to obtain a factor for correction, by determining the ratio which the standard death-rate of the place bears to the death-rate of the whole country. This is obtained by the rule of simple proportion, the second mean being unity. The recorded death-rate for the year, multiplied by this factor, gives the *corrected death-rate,* which will, therefore, be above or below the recorded rate, according as the factor is above or below unity. By dividing the corrected death-rate by the death-rate of the whole country, and multiplying the quotient by 1,000, the *comparative mortality figure* is obtained; that is to say, the number of deaths which will occur in the same number of the local population as, in the general population, will yield 1,000 deaths.

Classification of Causes of Death.—In the registration of causes of death, a certain amount of error is inevitable, for several reasons. In the first place, even the most competent practitioners are not infallible in diagnosis, and it is not always possible, when one pathological state is complicated by the advent of another, to determine which was the actual cause of the fatal termination. Next, the nomenclature of diseases is faulty, although ever tending toward ultimate perfection. Again, the true cause of death frequently is misrepresented intentionally for private or family reasons; thus, apoplexy, instead of suicide, and peritonitis, when the actual cause of the peritonitis is criminal interference.

Lastly, it is sometimes the case that no cause whatever is assignable, even after careful autopsy, and, obviously, such cannot be classified. With the existence of an indeterminate amount of error, it follows that caution should be exercised in comparing results representing a series of years, and allowances should be kept in mind with changes in nomenclature, when drawing deductions from what has been described as the classification of the more or less reliable guesses of a large number of more or less skilled observers.

Registration of Sickness, if it were possible, would afford a far more efficient index of the sanitary condition of the population than the registration of deaths, which gives us simply the number of cases of sickness which ended fatally, but no idea of the duration thereof or of the number of persons temporarily incapacitated. A disease ordinarily regarded as fairly dangerous may prevail very extensively in a mild form, and be attended by a very low death-rate, and, again, may exist to a lesser extent, but in an unusually severe form, with a high proportion of fatalities. Many diseases, again, are temporarily disabling and often widely prevalent, but play a small part in mortality returns. Tonsillitis, for example, is responsible for much discomfort and lost

time: its prevalence has some meaning, but its death roll is exceedingly small. Rheumatism is much more widespread than mortality returns would imply; chickenpox is relatively unimportant, but in some places its notification is required as a safeguard against the spread of smallpox incorrectly diagnosed as varicella; gonorrhœa, without being fatal, does more harm than commonly is supposed; and syphilis, also not immediately and directly fatal, sends its victims into the mortality returns through various avenues. But however desirable such registration may be, the obstacles in the way of its accomplishment are too numerous to admit even of hope, and, excepting in the case of infective diseases, which law requires shall be reported, there is no satisfactory method of obtaining an accurate idea of the health of a community.

Duration of Life.—Several expressions and methods are employed to denote and measure the duration of life, a problem with which the science of vital statistics is largely engaged. One of the most fallacious indications of longevity and sanitary condition is the *Mean age at Death* or *Mean Lifetime*, which is the sum of the ages at death divided by the number of deaths. This is unreliable, because it fluctuates very widely, according to age distribution; for in a community containing a large proportion of children and in which the birth-rate and, consequently, the infantile mortality are high, the average age at death will be lower than in another, equally healthy, in which these conditions do not obtain. Hence, it can only be employed with any degree of safety where the population constitution is uniform in all respects, and when the observations are carried along over a long period. The mean age at death, not of a few hundreds or thousands of individuals, but of an entire generation of population, is necessary to show accurately the mean duration of life, and this is determined only by means of life tables.

Probable Duration of Life signifies the age at which half of any number of children born will have died, so that they have equal chances of dying before and after that age. It is also called the *vie probable* and the *equation of Life*; but all of these terms are ill-chosen, for every possible duration of life has a certain probability, which may be determined by life tables.

Mean Duration of Life is another ill-chosen term with which the last-mentioned is often confounded, but which has an entirely different meaning. It is meant to express the probable duration of life from the date of birth. In an ordinary population, subjected to the usual disturbing influences of migration, it means present age plus the probable length of life after passing a given point, and is called commonly the *expectation of life* or *mean after-lifetime*. It is a term, which, by reason of its indefiniteness and looseness of application, it would be well to eliminate altogether.

Expectation of Life, or **Mean After-lifetime**, is the average number of years which an individual at any given age will continue to live, as shown by a life table. As applied to whole communities, it is the mean duration of life of a generation of individuals from birth to death,

and is regarded as the only true measure of the health of entire populations. Like others which have gone before, it is an unfortunate expression tending to confusion. "The term does not imply that an individual may reasonably expect to live a given number of years. The excess of those who die late is distributed among those who die early, 'those who live longer enjoying as much more in proportion to their number as those who fall short enjoy less of life.' Thus the expectation of life has no relation whatever to the most probable lifetime of any given individual." (Newsholme.)

"*Expectation of life* is an incorrect term: the time which it is *expected* a person will live is the time which it is an even chance he will live; it is the *vie probable* of the French, and is correctly expressed by 'probable lifetime.' The after-lifetime can only be the same as the probable lifetime on Demoivre's hypothesis—that the surviving form an arithmetical progression. The term 'expectation of life,' first used by Demoivre, is correct, on that supposition, which is, however, in itself quite erroneous. The idea intended to be expressed by 'expectation of life' is the *mean time* which a number of persons at any instant of age will live after that instant: it is the French *vie moyenne;* and this technical idea is strictly and shortly expressed by *after-lifetime,* a pure English word, formed on the same analogy as *after-life, after-times, after-age, after-hours.* The *after-lifetime* of men at the age of 30 is 33 years by the English Life Table: 33 years is not the precise time probably that anyone of that age will live, but the average time that a number of men of that age will live, taken one with another. *Age* + *after-lifetime* = Lifetime. At 30 this is 30 + 33 = 63, the average age which men now aged 30 will attain. At birth this is 0 + 40 = 40; when *lifetime* and *after-lifetime* are the same thing.

"The *lifetime* simply, without the addition *at a given age,* will serve to express in one word what is improperly called *the expectation of life at birth;* thus the *lifetime* of males in England is 40 years, the *lifetime* of males in *Manchester* is 24 years. Those who, from habit, prefer 'expectation of life,' can always substitute it for *after-lifetime;* from the use of which, in this paper, no ambiguity can arise." (Dr. William Farr, Eighth Annual Report of the Registrar-General, p. 279.)

Life Tables.—A life table, according to Dr. Farr, is an instrument of precision. "It may be called a *biometer,* for it gives the exact measure of the duration of life under given circumstances. . . . A life table represents a generation of men passing through time; and time under this aspect, dating from birth, is called age. In the first column of a life table, *age* is expressed in *years,* commencing at 0 (birth), and proceeding to 100 or 110 years, the extreme limit of observed lifetime."

In order to construct a life table, it is essential to have, as material, a knowledge of the size of the population and its age and sex distribution, and the returns of death for a year, or a series of years, arranged

according to age at death and sex; and for tools, certain abstruse mathematical formulæ which it is hardly necessary to consider here. The principle upon which the tables are based is that if a large number of persons, 100,000, for instance, born at the same time, were followed from birth to the grave, and their deaths recorded in the usual manner, the average age lived could be obtained by dividing the sum of their ages at death by their original number, and the number of deaths and of survivors at each period would be known. Another lot of the same size, observed elsewhere and living under different conditions, would give different results, and thus the influence of the discrepant conditions could be measured.

To insure as great accuracy as possible in constructing life tables, it is best to take the death returns for the entire intercensal period of five or ten years, and the mean population, for the experience of a single year may be exceptional. Tables can be constructed comprising each year of life or according to quinquennial periods, and are made for each sex. From them may be determined the probable proportion of a given number that will arrive at different ages, the probability of living a given time at each year or period of age, the mean after-lifetime at the end of any given year or period, and the aggregate future lifetime of the survivors at the end of each year or age period, or what is known as the *life capital* of the entire community.

The probability of living a given time for each year of life or age period equals the number of survivors at the beginning, into the number at the end of the year or period. The probable number of survivors at each year or period is obtainable directly. The mean after-lifetime at the end of any given year or period is obtained by adding together the years lived by the whole life-table population beyond the year or period, and dividing the sum by the number of survivors at that particular time. The life capital of a community, divided by the population, gives the average future lifetime; and into a hundred times the population, gives the percentage of annual expenditure of life capital, since the mean population equals years of life expended in a year.

For further information concerning this branch of vital statistics, and for further consideration of statistical methods, values, and errors, the reader is referred to the many standard works dealing with the subject.

CHAPTER XV.

PERSONAL HYGIENE.

In addition to the barriers which public hygiene interposes for the protection of the health of communities by protecting water supplies, disposing of sewage and other wastes, excluding exotic diseases by means of quarantine, providing for isolation of communicable diseases, destroying infectious matter by disinfection, regulating the conduct of dangerous occupations, providing for the inspection of foods, and throwing out other safeguards, the individual owes it to himself and to the community, of which he constitutes a more or less valuable unit, to erect such other barriers for his own protection as he can, by due regard to such habits of life as conduce to a healthy existence. It is his duty to maintain habits of personal cleanliness, to regulate his diet, avoiding all excesses in eating and drinking; to protect his body by suitable clothing; to take sufficient exercise in the open air; to keep his system in perfect working order throughout; to devote a sufficient part of each twenty-four hours to needful rest of mind and body; and to keep his immediate surroundings in as cleanly a state as his own person. This is the domain of personal hygiene.

Section 1. CARE OF THE PERSON.

It is hardly necessary to impress upon intelligent people the importance of personal cleanliness, for with such it is a matter almost of instinct. In the case of the naturally dirty, the attempt to educate in this particular is, as a rule, a hopeless task, and with such, the maintenance of cleanliness of body and surroundings can be obtained only by compulsion. There is in every civilized community an all-too-large proportion of persons who never bathe, and, indeed, regard a bath as a positive danger to health, as every physician who has had experience as a hospital interne or in practice among the ignorant poor can abundantly testify.

Bathing is of importance to health, both for its action in removing dirt and infectious matter of external origin, and for its influence in keeping the skin free from waste products of the system and in a condition for the proper exercise of its natural functions; for the skin is one of the most important natural defences.

Baths.—By an arbitrary division of temperatures, cold baths are those in which the water has a temperature below 65° F.; cool, between 65° and 80°; tepid, between 80° and 90°; warm, between 90°

and the normal temperature of the body; and hot, above this limit as high as the system can bear. Cold bathing is essentially stimulant: the cutaneous vessels contract at once, and send the superficial blood supply inward; the respiration is momentarily gasping in character, and then slowed and increased in depth. The whole nervous system and all of the mental faculties receive an immediate powerful stimulus. The pulse is somewhat slowed. On emerging from the cold water, the respiration and pulse return to their normal rates, the cutaneous vessels relax and dilate, and the return of the blood in increased volume to the surface gives a sensation of warmth, which is increased by the process of "rubbing down." This is known as the "normal reaction."

The cold bath is taken best in a tub in which the whole body may be immersed; but in default of the necessary means, a sponge, saturated with water, applied repeatedly to the various parts and squeezed out, forms a desirable substitute. A shower bath is better still, especially one admitting of regulation of the temperature.

The proper time for cold bathing is on rising in the morning; never on retiring for the night. Cold baths should not be taken by those advanced in years, in whom the arteries are atheromatous, nor by those with abnormal circulation, who do not quickly react.

Not the least in importance of the effects of cold bathing is the immunity which its devotees appear to enjoy against taking cold. Many of those who practise cold bathing the year round have no experience whatever with colds, and can withstand exposure which, to others, is productive of much illness.

In sea bathing, the element of enjoyment has a most important influence. The salts are commonly supposed to be the chief source of benefit, and, in consequence of this belief, many persons are in the habit of dissolving in their daily bath in the household a quantity of more or less dirty material, sold at a price which insures at least a fair pecuniary return, and known as sea salt. The influence of the salts contained in sea water is *nil*, and the benefits of sea bathing are the result of the physiological action of cold, the attendant exercise of swimming, the pure air, the absence of domestic and business cares (if on vacation), and the sense of enjoyment.

Warm and hot bathing cause dilatation of the cutaneous vessels and more or less profuse perspiration. Respiration and pulse are increased in frequency, and a general soothing effect is produced. Hot bathing is a most grateful means of reducing soreness of the muscles after violent exercise and a valuable assistant in the treatment of insomnia. For purposes of personal cleanliness, warm and hot baths are more suited than cold, since they can be borne longer with comfort, and the relaxation of the skin which they induce is more favorable to complete removal of the adherent matters.

If means for complete bathing are not at hand, the individual should in any event give daily attention to careful cleansing of the axillæ, groins, genitals, and feet, as well as of the hands and face.

Section 2. REGULATION OF THE DIET.

It is obviously impossible to formulate any system of rules, applicable to all classes, for the selection of diet and the regulation of hours with reference to the daily duties of life, but general rules concerning some aspects of the question may be laid down. The suggestion of light breakfasts, somewhat more substantial luncheons, and hearty dinners at close of day, with periods of mental and physical rest after each meal, is easy to make; but the busy lives which the great majority of the population lead, and the widely different conditions of life and occupation, make its general acceptance and adoption quite beyond the bounds of possibility. It is a common habit of writers on personal hygiene to compose menus for the several daily meals, to suggest the amount of time which should be devoted to the consumption of each, and to recommend the avoidance of physical or mental labor for varying periods before and after each meal, in order that the digestive apparatus may proceed with its work under the most favorable conditions for its uninterrupted completion.

The adoption of most of such recommendations, however, presupposes a curious state of the conditions of life, including an absence of any marked preferences in the matter of articles of diet, a complete mastery of one's time without reference to the demands of occupation, and pecuniary independence.

General rules may be offered to the effect that the diet should consist of wholesome articles of food; that these should be consumed in sufficient, but not excessive, amounts; that they should not be hurriedly bolted; and that as much time as is consistent with the needs of one's occupation should be allowed after each meal, before proceeding to a continuance of work. Obviously, in these particulars each person must be a law unto himself, and the greater the observance of general hygienic principles, the better the physical and mental well-being.

Section 3. REST AND RECREATION.

For the repair of the daily wear and tear of a busy life, a reasonable period of rest of body and mind is indispensable. Nervous and mental breakdown result from overwork and absence of recreation, but it is impossible to make any rule as to what may be regarded as a safe limit of the amount of work which may be performed. Monotony of life is, perhaps, as potent a factor in mental breakdown as overwork, as is evidenced by statistics showing the high percentage of insanity among farmers and farmers' wives in sparsely settled districts. Mental worry, also, is far more potent than mere mental activity in causing physical and mental degeneration. Recreation is a most important remedy, therefore, for the prevention of monotony and worry.

It is impossible to lay down any rule, governing the amount of sleep, that can apply to all persons indifferently, since active minds may need much less than what commonly is regarded as a minimum general

requirement, and persons of conspicuously low mental capacity may require much more. It is generally accepted, however, that for the repair of waste, the average man needs to pass at least one-third of his time, namely, eight hours a day, in sleep.

Section 4. PHYSICAL EXERCISE.

It is essential to the maintenance of a completely healthy condition that a well-nourished body shall be exercised properly in all its parts. The muscular effort involved in what we designate as physical exercise and in the pursuit of certain callings which necessitate bodily activity affects not alone the general musculature, but all the organs of the body as well; the heart, the lungs, the digestive apparatus, the skin, the kidneys, the brain, and, in short, every part. The heart and lungs being stimulated to increased action, an increased supply of oxygenated blood is sent to every part, bringing with it the essentials to full nutrition and conveying to the eliminative channels the ultimate products of metamorphosis. The special stimuli of the various organs are excited, and thus the several functions are maintained in a normal state of activity.

In order to gain a full appreciation of the benefits of physical exercise, one needs but to compare the rugged condition of the well-nourished laborer in the fields or of the student or man of business, who, in the intervals away from his daily work, seeks recreation in outdoor exercise or indoor gymnastics, with that of the pent-up, sedentary operative or the indolent seeker after pleasures involving inaction. Whether the work of the individual be that of the hands or brain, it is sustained better, if the system is kept active in all its functions and parts.

Effects of Active Exercise.

Circulation and Respiration.—Muscular effort causes the heart to beat more rapidly and with greater force, so that more blood is sent through the lungs and all parts of the body, including the substance of the heart itself. Unless the exercise is excessive in duration or violence, the increased action is regular and equal, and cessation of the exercise is followed by gradual slowing, until the rate is below the normal; and then by return to the natural rate. With excess of muscular effort, the pulse becomes quick, small, and, often, more or less irregular, and even during the fall in rate in the interval of rest, it may be intermittent. Excessive rapidity, irregularity in pulsation, and inequality of volume are indicative of the necessity of rest and of danger from continuance.

The increase in the pulmonary circulation is accompanied by increase in respiratory action, so that a larger volume of blood is forced through the lungs and comes in contact with an increased air supply, from which it receives the necessary increase in oxygen for conveyance to the tissues, and to which it gives up its carbon dioxide, aqueous vapor, and other waste products, for removal from the body. According to

the researches of Pettenkofer and Voit, the oxygen absorbed during an ordinary working day, with the usual interval for rest, is about one-third greater in amount than during a day of inaction, and the carbon dioxide produced and eliminated is increased about two-fifths. During exertion, the action of the chest should be impeded as little as possible by tightly fitting clothing and other restrictions.

Excessive exercise causes labored breathing and sighing, which are indications that the lungs are too much congested, and that rest is required.

Continued excessive exercise may bring about palpitation, dilatation, hypertrophy, and even valvular lesions of the heart, and congestion of the lungs, accompanied, sometimes, by hæmoptysis. Sudden unusual effort may cause rupture or other injury of the blood-vessels, and, rarely, even rupture of the heart.

Deficient exercise favors weakening of the heart's action, dilatation, and fatty degeneration; and in those with inherited predisposition, the preparation of suitable soil for the reception and development of the organism of tuberculosis.

Skin.—In consequence of the increased blood supply sent through the cutaneous vessels, the latter dilate and the skin becomes reddened. Heat is brought from the interior of the body and radiated from the surface, and a farther cooling effect is caused by the evaporation of the sweat which is poured out by the sweat glands. Thus the excess of heat produced in the system through exercise of its various parts is eliminated and the body temperature kept in a state of equilibrium. The amount of water given off by the lungs and skin during a day of average work was shown by Pettenkofer and Voit to be nearly twice and a half that eliminated during the same period of rest.

With the water of the sweat, the body loses salts, especially sodium chloride, and fatty acids and other organic substances.

During exercise, while the skin is active, there is little danger of chill, even though the skin be lightly covered or even exposed; but as soon as the body rests, the temperature falls, and sweating and evaporation continue, so that it is important to protect the body against sudden checking of the skin's action and chilling of the surface. This is done best by means of clothing of low heat conductivity, preferably woollen.

With normal action of the skin, the body temperature remains fairly constant, the heat of the blood, even during most violent exercise, rarely rising much more than a degree Fahrenheit above the normal. During work, a decided rise in temperature indicates lessened evaporation from the skin and points to possible danger from heat apoplexy.

Nervous System.—It is a common belief that exercise has no effect in increasing the powers of the mind, this belief being based on the supposition that the greater expenditure of nervous energy called for in the exercise of the muscles is opposed to intellectual development or accomplishment. In support of the idea that great muscular power and exertion are incompatible with marked mental attainments, the

fact is often cited that trained athletes, as pugilists and wrestlers, are conspicuously stupid. But admitting that this is true, it may also be said that these persons are stupid in spite of rather than because of their physical development and training; and the fact may be pointed out that in our schools and colleges the chosen athletic representatives rank, as a class, even higher than the average of their non-athletic brethren. Intellectual ability is incompatible with the embracing of pugilism as a calling, but is quite consistent with a high degree of physical perfection and bodily exercise. Furthermore, a reasonable degree of activity appears to be necessary to the performance of mental labor, for without proper nutrition and exercise of the system, the nerves and nerve centers must suffer with other parts, even as they must share in the benefits of healthy and vigorous living.

One part of the general system cannot monopolize the benefits of training: the muscles, for example, cannot be trained without the participation of the nervous system in the good results, nor, on the other hand, can they be abused without injury to other parts as well, for motor activity is the result of nervous energy, and all fatigue is nervous fatigue. As evidence of the beneficial influence of exercise on the nerves may be cited the greater readiness with which trained muscles respond to volition.

Deficient exercise is a common cause of morbid excitability, manifested by irritability of temper, sensitiveness, and that form of nervous unrest commonly known as fidgets.

Digestive Apparatus.—The great increase in the excretion of carbon dioxide and in general cellular activity causes a demand for food, and the appetite is increased, especially for proteid matter and fats. Digestion is assisted, and absorption is hastened. The volume of the excreta is lessened by reason of a diminished content of water, due to increased elimination through the skin and lungs. Lack of exercise, on the other hand, tends to diminish appetite and the powers of digestion.

Kidneys.—The amount of urine is lessened by reason of increased loss of water through the skin and lungs. The inorganic salts are commonly increased, both relatively and absolutely. Urea is not increased, and may even be diminished, as shown by Pettenkofer and Voit, in which case, a more than compensatory increase occurs during the interval of rest.

Effect of Exercise on Weight.—The effect of systematic regular exercise on weight is by no means constant, but is influenced by the condition of the body in the beginning, and by the amount and variety of the food ingested. Many persons shortly after beginning a course of training for the reduction of weight or, more correctly, of size, find that a reduction in girth is accompanied by an increase rather than a diminution in weight. This means simply that the system has drawn upon its stored fat for fuel, this fat being most conspicuously placed in the vicinity of the waist line, and has built up tissues elsewhere for the increased work of moving the various levers of the body. This increase has its limitations, and when the maximum has been reached,

the fall in weight, due to utilization of surplus fat, may continue until a point is reached when the curve of weight approximates a horizontal line, and the person may be said to be in perfect physical condition. The marked losses in weight which occur during violent exercise are soon counterbalanced by ingestion and absorption of food and drink.

Amount of Exercise Required.—Since, in the ordinary routine of life, a considerable and varying amount of physical work is performed, it is impossible to fix any rule concerning the exact daily amount of exercise which a healthy normal adult should take. With the vast majority of persons, all the exercise needed is taken as an inseparable element of their regular occupation, and any additional work is performed as a means of recreation. On no other ground can be explained, for example, the evening bicycle ride of the letter-carrier after the monotony of his daily rounds on foot, or the game of ball begun at the close of the day's work by the hands from the mill or foundry.

A fair day's work for an adult may be said to be equivalent to about 300 foot-tons, a hard day's work to 400, and a very hard day's work to 500 foot-tons. The latter is about the amount of work performed by a soldier of average weight marching at ease with his kit twenty miles over a level surface at the rate of three miles an hour.

It has been reckoned by Haughton that, in walking on the flat, one performs an amount of work equivalent to raising a certain proportion of his weight through the distance travelled, the proportion varying according to speed. The work performed is reckoned by the following formula:

$$\frac{(W + W') \times D}{2240} \times C = \text{number of foot-tons.}$$

W = weight of the person.
W' = weight carried.
D = distance in feet.
2240 = number of pounds in a long ton.
C = coefficient of traction.

The coefficients of traction, as determined by Haughton for different rates of speed, are as follows:

Miles per hour.	Coefficient.
1.818	$\frac{1}{28.27}$
4.353	$\frac{1}{15.70}$
10.577	$\frac{1}{7.51}$

From these, the coefficients for any rate may be determined. For two, three, four, and five miles per hour, they are approximately $\frac{1}{26}$, $\frac{1}{20}$, $\frac{1}{16}$, and $\frac{1}{14}$, respectively. Thus, a man weighing 175 pounds, walking 10 miles at the rate of 4 miles per hour and carrying 25 pounds, would, according to the formula, do nearly 300 foot-tons of work—

$$\frac{(175 + 25) \times 52{,}800}{2240} \times \frac{1}{16} = 295.25$$

In ascending a height, a man lifts his entire weight through the vertical distance travelled. Thus, the same man, carrying the same weight, climbing six flights in an ordinary office building, would do about 8 foot-tons of work, reckoning the distance climbed as 90 feet.

For those who do no regular, ordinary physical labor, it has been estimated by different authorities that exercise equivalent to from 100 to 150 foot-tons is sufficient for the maintenance of a fair state of health. But this should not be pushed to the extent of being exhausting or irksome. When, in the course of exercise, the body begins to be fatigued or the heart and respiration to be embarrassed, rest is required; for excessive exercise confers no benefit. Severe prolonged exercise may cause dilatation of the heart, aneurysm, and respiratory disorders.

Kinds of Exercise.—Exercise as a hygienic measure may be divided into outdoor work, including walking, riding, and athletic sports, and indoor work, or systematic gymnastic exercises. The former, preferred by all English-speaking people, are carried on under far more healthy conditions and bring with them a much greater measure of enjoyment than the latter, which are preferred on the Continent, more especially by Swedes and Germans. Indoor work in the gymnasium is, as a rule, purely work, without the element of pleasure either in anticipation or during its continuance, and is performed as a serious duty. It is carried out from day to day for a longer period, if done in company with others, as in a class; in which case, emulation may stand in the place of actual enjoyment. But ordinary indoor exercise with Indian clubs, dumb-bells, chest-weights, and similar appliances, carried on alone in one's room, is usually most unsatisfactory in its results.

There are some, doubtless, who regularly take a certain amount of this class of exercise, enjoy it, and profit by it; but, commonly, the enthusiasm which attends the purchase of the appliances declines in a marked degree by the end of the third or fourth day of use, and has disappeared in a week. Soon the exercise, simply a duty, develops into a bore, for the monotony of this kind of work, into which no sense of achievement enters, except that from the accomplishment of a wearisome round of strokes measured by hundreds, produces a distaste; and soon the work becomes spasmodic, the intervals growing longer and longer, and finally is abandoned completely.

Golf.—This exceedingly popular game appears to be an ideal form of exercise for all ages above early childhood, and particularly for those whose lives are essentially sedentary or whose age precludes them from following the more violent games. The amount of work performed in going once over a course is very considerable, but it is done in such a way and under such surroundings, with ever-changing scene, that, at the time, it is hardly appreciated. The mind is pleasantly engaged in speculation as to the possibility of achieving certain results, and is filled with pleasurable emotions when the effort is crowned with success; the body is gently exercised in all its parts by a form of work performed because it is so essentially a means of enjoyment. It cannot

be abused as are so many other sports, and there is no necessity for quick and violent action, as in tennis and football.

Wheeling.—Wheeling involves very largely the entire muscular system, and brings into play groups of muscles, the existence of which has not before been appreciated by the beginner. With the wheel, one may take any desired amount of gentle, moderate, or violent exercise. It gives a constant change of scene and the pleasurable sense of motion, both of which are of value to the tired mind. It is not the particular form of muscular exertion that is the incentive to long exercise on the wheel, but the pleasure which it gives; for no more monotonous exercise can be devised than riding a stationary bicycle in a gymnasium, while, on the other hand, many who would regard an errand, involving a walk of a mile, as a hardship, will, without demur, wheel five times that distance for the same end.

Tennis, etc.—Tennis, football, baseball, and other outdoor sports are comparatively violent for the majority of people. They bring the whole body into action and are valuable, if not pushed too far. They do not admit of varying the pace according to the fatigue of individual players, in which respect golf and wheeling possess an advantage.

Rowing is also a very healthful form of exercise, but the violent exertion required in the sustained effort of racing is not always a benefit.

Section 5. CLOTHING.

The objects of clothing are, aside from motives of decency, to protect the body from the sun's rays in hot weather, from the chilling influence of winds in all weathers, from rain and other forms of wet, and from mechanical and other external injuries and discomforts; to conserve the body temperature and prevent interference with the natural functions of the skin; and, finally, to adorn the person. The proper fulfilment of these various objects is dependent upon the nature of the material, the looseness of its texture, its color, its hygroscopicity and heat conductivity, and its special adaptability to some particular purpose.

Color.—The heat of the sun's rays is absorbed to the greatest extent by black materials, and least by white. Next to black come the dark shades of blue, and then, in order, green, red, and yellow. Heat is reflected most by white, and then, in order, the light shades of yellow, red, green, and blue. The color of undergarments (not exposed to the rays of the sun) exercises no influence whatever.

Texture.—The looser the texture, the greater the amount of air in the interstices; and air being a very poor heat conductor, other things being equal, a loosely woven fabric prevents loss of body heat in a still air more than one of closer texture. Thus it is that a thin, loosely woven garment of woollen is warmer to the body in a still, cold atmosphere than an equal amount of closely woven material of the same or other kinds. The same result is attained by wearing a number of garments, one over another, so that, having layers of con-

fined air between, they act in the same way as double windows on a house. The value of furs as conservators of heat is largely due to the amount of air retained between the individual hairs.

Impermeable materials, being absolutely wind-proof, and hence permitting no natural ventilation through their substance, are very warm, but have serious disadvantages, the most important of which is the retention of the transpired moisture of the body, which collects on the surface and is absorbed only in part by the clothing next thereto. Against rain and cold winds, impermeable materials afford very great protection. Winds act in two ways to chill the body: by constant removal of the air in contact with the body and warmed by reason of contact, and by hastening evaporation of the moisture within the substance of the clothing.

Heat Conductivity.—Materials vary widely in their power of heat conduction. Among the textiles, linen and cotton are by far the best conductors, and wool the poorest; but since the conductivity of a garment is governed mainly by the looseness of texture, it follows that the same amount of a good conductor, loosely woven, may be warmer than wool woven very closely. But the fabrics made of the best conductors are commonly very closely woven, and of wool are of varying degrees of looseness.

Hygroscopicity.—Fabrics hold moisture in two ways: first, by retaining it in the interstices between the fibers; and, secondly, by absorption directly into the substance of the fibers. The moisture held in the interstices gives the sensation of dampness or wetness, and may be largely removed by pressure, as in wringing; that absorbed into the fiber may be very large in amount without giving any sensation of dampness, and it cannot be expelled by pressure. The latter is known as hygroscopic moisture.

Materials of animal origin are more hygroscopic than those from the vegetable world, and while they absorb water readily, they part with it more slowly by evaporation. Thus it happens that a person, sweating to the same extent and under the same general conditions, feels less sensation of chill on resting from his exercise or work when clothed in woollen, than when his dress is linen or cotton. In the latter instance, the moisture is held more largely in the interstices, and the garment may be distinctly wet, and then adheres to the skin, which, as evaporation proceeds, becomes chilled through rapid abstraction of the heat required in the process; whereas, in the former, the evaporation is gradual and the chilling much less perceptible or unnoticeable. But here, again, a hygroscopic material, very closely woven, may be incapable of holding as much moisture without imparting the sensation of distinct wetness, as one of a loosely woven substance of low hygroscopicity.

Materials.

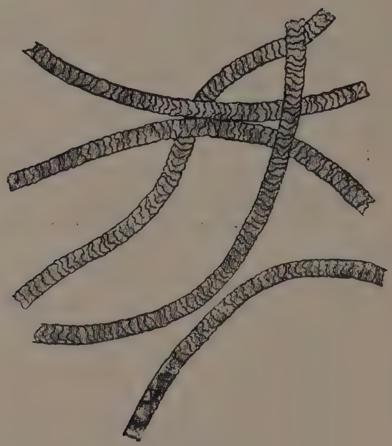
The materials employed in the making of clothing come mainly from the animal and vegetable worlds; from the former are derived the

wools of various kinds, silk, furs, feathers and down, and leather; from the latter, the principal derivatives are cotton and flax (linen), and, of lesser importance, straw, hemp, jute, and rubber.

Wool.—Wool of various kinds is yielded by a number of different genera of animals. That in commonest use and to which the name is very generally restricted is derived from the sheep. Other kinds include mohair from the Angora goat; kashmir, or cashmere, from the Thibet goat; camel's hair and alpaca, from *Auchenia pacos*, a cameloid ruminant of South America. But the terms mohair, cashmere, and alpaca commonly refer to cotton and sheep's wool imitations containing no trace of either of these more expensive wools.

Under the microscope, the fibers of wool are seen to be cylindrical and translucent, and covered with small imbricated scales which, like those of a fish or the feathers of a bird, run all in the same direction.

FIG. 109.



Woollen fibers.

They are sharpest and smallest, and hence most numerous, in the finest sorts; as many as 2800 and as few as 500 to the inch have been counted respectively in the best and very inferior kinds. They give to the fibers the tenacity with which they cling together when woven, and the readiness with which, when wet and subjected to pressure, as rubbing or wringing, they mat together and cause shrinking of the fabric. They are shown in Fig. 109, which is drawn from a specimen of fine Saxony crewel.

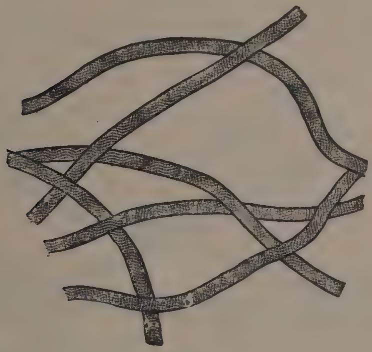
Woollen goods, being poor conductors and containing much enmeshed air, are the most valuable of all textiles for general purposes in all climates, and particularly in those in which abrupt wide changes in temperature occur. In very hot climates, they are inferior as outer garments to cotton and linen, which, being better conductors and reflectors, assist more in keeping the body comfortably cool. But for undergarments, wool is much better as a protection against chilling after

active exercise, on account of its hygroscopic properties; the vapor from the body is condensed and absorbed, and the heat, which becomes latent when the moisture is vaporized, is set free, and the evaporation from the fabric to the external air proceeds slowly and without the chilling effect observed when one sits in clinging wet cotton or linen, which feels cold in proportion to the rapidity with which it dries.

Woollen fabrics are much subject to adulteration with cotton and other cheaper materials. What are known as flannelettes are very commonly made wholly of cotton or with a very small percentage of wool, although the name is intended to convey the idea that wool is the sole or chief material used. What some are pleased to designate "sanitary flannel" is often largely or wholly cotton. Shoddy is a fabric made with varying proportions of old ravelled woollen and other cloths with a minimum of new wool. It has, as may be supposed, a much inferior tensile strength and less uniformity of texture than woollen of good quality.

Silk.—Silk is the spun fiber produced by a number of species of insects, especially the larvæ of the bombycid moths, called silkworms,

FIG. 110.



Silk fibers.

to form cocoons or protective coverings when about to assume the chrysalis stage. The cocoon in which the chrysalis is killed yields an exceedingly fine thread, consisting of two agglutinated filaments. This thread, when unwound, measures more than two miles in length, and when spun, yields in the neighborhood of 500 yards of silk thread. The outer part of the cocoon is of inferior quality, and is known as floss.

Silk is very hygroscopic. It is a poor heat conductor and a perfect non-conductor of electricity. It has great affinity for anilin and other dyes.

Under the microscope, the fibers appear as structureless tubes, and show no scales or surface markings, such as are seen on wool. They are represented in Fig. 110. Before being woven into fabrics, silk is commonly weighted with salts of tin and iron, with which it forms

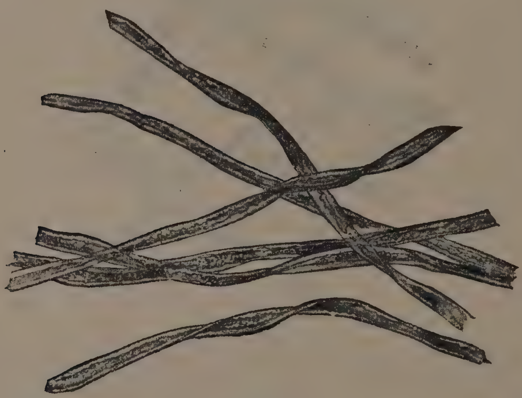
stable chemical compounds. Weighted silk, subjected to the action of a Bunsen flame, parts with its organic constituents, but retains its structural appearance.

Silk is very subject to adulteration with other fibers and to complete substitution by artificial preparations. One form of artificial silk, invented, in 1884, by a Frenchman, Count Chardonnet, is made from prepared cotton or wood fiber. It possesses a very silky luster, and was at first very inflammable and even explosive, being practically nitro-cellulose; but later, the product was subjected to further chemical process and made harmless. Another form, invented by Fremery and Urban, is made from cotton waste, and is produced much more cheaply. Still another form, invented by Professor Hummel, of Leeds, is made from gelatin at an expense of about $1.15 per pound. It has a low tensile strength, but may be employed in a mixture with genuine silk or fine linen or cotton thread to make a durable fabric.

Silk is used chiefly in the manufacture of silks, satins, velvets, crape, and plush.

Cotton.—Cotton is the soft woolly fibers appendant to the seeds of the cotton plant (*Gossypium*), consisting of cellulose, and varying in

Fig. 111.



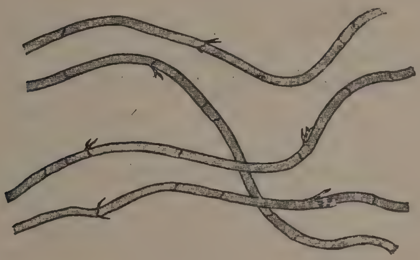
Cotton fibers.

length from a half to two inches. It is contained with the seeds within the boll, which, when ripe, bursts and allows the fibers partially to escape. Microscopically, the fibers appear flattened and twisted; they have somewhat thickened borders, and some show a central canal. They are shown in Fig. 111. They are freed from the seeds by the cotton-gin, then cleaned and spun into thread, and woven into fabrics of various kinds, including what is known commonly as "cotton cloth," sheeting, towelling, jean, drill, and others. For the purpose of giving weight, stiffness, and improved appearance, starch aud other materials are commonly employed in finishing. Cotton is employed also with wool and

other materials as an adulterant or to combine the useful properties of each, as, for example, in merino, which is much used in the manufacture of underclothing and stockings. Cotton is very durable and hard, has low hygroscopicity and high heat conductivity, does not shrink in washing, and is particularly adapted as a material for outer garments for hot weather.

Linen.—Linen is a fabric woven from the soft silky fiber obtained from the outer covering of the stalks of the flax plant (*Linum usitatissimum*), which are allowed to rot until the proper stage of decomposition is attained, when they are beaten and carded. They yield about a sixteenth of their weight of fiber. Microscopically, the fibers appear as cylinders marked at regular intervals by striæ indicating cell divisions. (See Fig. 112.) Twisted into thread, they are used in weaving various fabrics known as linen, cambric, damask, diaper, lawn, and huckaback. Linen goods are smooth and lustrous, heavier than cotton, durable and hard, of low hygroscopicity and high heat conductivity. They are

FIG. 112.



Linen fibers.

especially suited for shirtings, sheetings, and outer garments for hot climates.

Rubber.—India rubber is a product derived from the milky juice of various tropical plants. It is soluble in ether, naphtha, chloroform, and carbon disulphide. Its elasticity is impaired and destroyed by long exposure to the air and by extremes of atmospheric temperature, but is made lasting by the addition of a small amount of sulphur in the process known as *vulcanizing*, discovered by Goodyear in 1844. This process, in addition, insures increased durability, flexibility, and impermeability to air and moisture. To the latter quality, rubber owes its extensive employment in articles of dress, including galoshes and other foot coverings, and outer garments made of rubber-sheeting or waterproof cloth, known as mackintosh. The latter is made by applying a solution of rubber in successive layers to cotton or other fabric, so that it shall be made impermeable to water.

Rubber garments are a very useful protection against wind and rain, but are objectionable on the score of being hot and confining the watery vapor given off by the skin, thus bringing about a condition of great

discomfort. They should, therefore, be ventilated as much as is practicable, especially if worn in moderate or warm temperatures.

Clothing can be made waterproof and, at the same time, permeable to air, by a number of processes, and such material has an obvious advantage over ordinary mackintosh and other impermeable fabrics.

Leather.—Leather is the skins of animals, chiefly the ox, calf, horse, sheep, and goat, prepared by tanning and tawing. In tanning, the skin is soaked in vats containing an infusion of oak bark rich in tannic acid, which causes the formation of tough, insoluble tannates of the gelatinous and albuminous constituents of the skin. In tawing, mineral astringents are used instead of oak bark; the end is attained more quickly, but the product is of inferior quality. After the process of tanning or tawing is completed, the skin, now tough and stiff, is subjected to a series of processes, collectively known as currying, whereby it is made soft, smooth, pliable, and ready for use.

Leather, being hygroscopic, takes up perspiration from the foot and gives it off to the outer air; but if it is made impermeable, as in the case of the so-called "patent leather," the latter office cannot be performed. That the perspiration of the foot is given off through the boot, is sufficiently proved by the dampness and dull appearance of the leather of a well-polished boot after half a day's confinement in a rubber overshoe. Although permeable to this extent, leather is sufficiently waterproof for ordinary use, and may be made more so by the external application of grease.

Fur.—Fur as an article of clothing presents the great advantage of impermeability to wind with that of very low heat conductivity, due in greatest part to the large volume of air retained between the hairs. No other kind of material is comparable as a protection against wind and cold.

Felt.—Felts are made from the hairs of various animals, but the best, such as are used for hats, both soft and stiff (the Derby, for example), are made from the hairs of the cony. They are made without weaving, the hairs being blown against a revolving, perforated, metallic cone of large size, connected with an exhaust blower. When a thin coating has formed, a jet of steam is directed against the cone, and then the felt in its first stage is stripped off in a coherent mass, held together by the minute imbrications on the individual hairs. By means of further processes of steaming and steeping, the mass is reduced in size and increased in wall thickness through shrinkage.

Adulteration of Clothing.

Fabrics are much subject to adulteration by admixture of fibers of lower value, as of cotton or shoddy to wool, and by starch and mineral matters to give weight. Many of the cheapest of cotton fabrics are so heavily sized that a single washing will convert a stiff, apparently close-woven piece of goods into a worthless, coarse, flimsy material fit only for sieves.

Chemical analysis of fabrics is not always to be relied upon, although fibers of vegetable origin behave very differently from those from the animal world; and any attempt on the part of an inexperienced person to determine the percentage of different kinds of fiber in a mixture is sure to lead him to two conclusions, namely, that he has wasted his time, and that much of what has been written concerning the behavior of different fibers when treated with strong chemicals is remarkable only for its small measure of truth.

Microscopical examination is a far simpler and much more satisfactory method of determining the composition of a fabric. A few threads, teased apart and examined with a moderately high power, will reveal the nature of the fibers and yield approximately accurate quantitative results. Shoddy commonly shows fibers of wool of different shades of color, but this finding is by no means to be accepted as conclusive evidence that a specimen of fabric under examination is shoddy, since only plain goods of a solid color yield fibers all of one shade. But if the fibers show abrupt changes in diameter and partial obliteration of the imbrications, it may be safely concluded that the specimen is shoddy, since fresh wool is fairly regular in diameter and shows sharply marked imbrications.

Poisonous Dyes.—In the dyeing of textiles and other articles of clothing, a great variety of substances of vegetable and mineral origin are used, and many of them have been known to produce serious results. Among them may be mentioned potassium dichromate, zinc chloride, compounds of arsenic and antimony, and certain of the anilins. An outbreak of 34 cases of acute dermatitis, occurring among a number of workmen who had just donned new overcoats, is reported by Taunton.[1] On the first wet day, when the coats were worn, the wrists, where they came in contact with the edges of the wet sleeves, became inflamed. In 1 case, the legs were similarly affected, the trousers being wet and rubbed against by the skirt. In 3 cases, the arms were affected. On soaking the cloth in water, it yielded free zinc chloride.

According to U. S. Consul Hughes, of Coburg, in a communication to the Department of State, under date of April 23, 1901, Dr. Adolph Jolles has demonstrated before the Vienna Medical Society the harmful effects of wearing pearl-gray silk stockings, colored by repeated baths in a solution of zinc chloride. It was shown that a large amount of the salt was present in the finished goods when packed for the market, and that the danger therefrom by absorption was very great.

A serious case of poisoning by anilin black is quoted by Cartaz,[2] from a report of Landouzy and Brouardel to the Academy of Medicine of Paris. A child of seventeen months became suddenly unconscious and apparently asphyxiated, and, although restored, remained very ill for forty-eight hours. Then the brother of the child and a number of other children were seized in the same way. All of the victims wore shoes which gave off a peculiar penetrating odor, and were found to

[1] Lancet, December 6, 1898.

[2] La Nature, August 4, 1900.

have been dyed with anilin black. Animal experimentation proved that absorption of this by the skin is favored by heat and moisture, which conditions are present in a tightly laced shoe, and may bring about alteration of the blood corpuscles and asphyxia.

Another case is reported by Besson,[1] of a child of six years, who, after wearing a pair of new shoes during the forenoon while at play, became cold and cyanosed in the afternoon, but was relieved by heat and stimulants within twenty-four hours. The shoes had been polished with a preparation which had a distinctly nauseating odor, and contained 91 per cent. of anilin.

Laurent and Guillemin[2] report still another, in which six children, all of one family, were seized, after wearing new shoes upon which the anilin polish had not completely dried, with sudden symptoms of poisoning, which included pallor of the face, bluish discoloration of the lips and nails, dilated pupils, headache, vertigo, albuminuria, great muscular weakness, slow pulse, slight convulsive movements, and unconsciousness. Recovery occurred in from one to three days.

It is commonly believed that arsenic in dyed and printed textiles is present as an accidental impurity of various anilins, but this is far from being the truth, since white arsenic itself is used in several processes for the purpose of adding brilliancy to the colors. Thus, in the so-called arsenite of aluminum process, the dye, dissolved in acetic acid or water, is mixed with acetate of aluminum and white arsenic in glycerin, and the mixture is employed in printing the pattern; next, the printed fabric is subjected to moist heat, and the anilin, in combination with the arsenite of aluminum formed, is fixed in the fibers in an insoluble form.

Selection of Clothing.

The properties of the various materials used in the manufacture of textiles have already been given in some detail, and further consideration of underclothing and outer garments, beyond a word of caution against unnecessary weight of clothing and undue constriction of any part of the body is, therefore, unnecessary. In the matter of constriction, no part of the human body is so abused as the foot, especially that of woman. Boots, shoes, and stockings should fit the foot, and there should be no such thing as the agony which many people expect as a matter of course in the process of "breaking in." The toe should be neither pointed nor cut square, and the whole sole should follow the natural outline of the foot. The sole should project a reasonable distance from the upper, in order to give firmer support and increased protection to the soft parts from contact with loose stones and other objects. The heels should be low and broad. High heels are worn, not for comfort in walking, but to increase the height of the body and diminish the apparent length of the foot. For purposes of successful deception, they take about equal rank

[1] Journal des Sciences médicales de Lille, 1901, No. 10.
[2] Journal des Praciciens, March 2, 1901.

with hair dyes and artificial complexions. Their use conduces to weakness of the arch, atrophy of the muscles of the leg, and a variety of other abnormalities. The heel of the foot should fit snugly in its place within the shoe, but the toes should have sufficient room for freedom of movement, yet not enough to cause chafing and excoriations. The upper should fit snugly, but not too tightly, about the ankle and over the instep; otherwise, the foot will drive forward and cramp the toes.

CHAPTER XVI.

INFECTION, SUSCEPTIBILITY, IMMUNITY.

Exciting Causes of Disease.—The exciting causes of infectious diseases are parasites belonging to both the animal and the vegetable kingdoms. They gain access to the system, and if the individual be receptive or "susceptible," proceed to bring about disturbance of function, some by mechanical obstruction, some by destroying the blood corpuscles which they invade, some by methods still unknown; but mostly through highly toxic substances which they produce and which act locally or generally, as the case may be. Most of those which have been discovered belong to the vegetable kingdom (bacteria); some are animal organisms (protozoa). Of many of the common diseases, notably the exanthemata, the still undiscovered causes belong probably to the latter class, if we may reason by analogy from the discoveries relative to smallpox by Councilman and concerning the cause of scarlet fever by Mallory.

Disease germs are endowed with life; and for its continuance and for multiplication within the tissues, certain favoring conditions are necessary; invasion of a system offering hostile conditions begets no disease. Introduced in sufficient numbers, and finding their environment favorable, they multiply, as a rule, and eventually make their presence manifest through the symptoms produced by their toxic products or because of their power to obstruct or destroy. They differ essentially from poisons in the ordinary sense; for poisons, although causing disturbance of function, resulting likewise even in death, do not reproduce themselves within the tissues. An injection of aconitine, or of morphine, or of tetanus toxin, or of snake-venom does not grow in the system, and hence, if not sufficiently powerful to cause disturbance of function, it will not become so with lapse of time; but the introduction of a few streptococci, for example, may be followed by rapid multiplication in geometrical progression and result eventually in a fatal septicæmia.

Channels of Infection.—Of the various channels of infection, the most important are the respiratory and alimentary tracts (tuberculosis, influenza, diphtheria, typhoid fever, cholera, dysentery, etc.); but some of the most devastating of human scourges are spread through inoculation into the skin (malaria, yellow fever, etc.). Invasion of the tissues by disease germs may be followed by localized infection with general disturbance of the system due to their toxic products (as in diphtheria and tetanus), or by general infection and disturbance (as in the septicæmias).

Infection and Contagion.—The terms *infectious* and *contagious* have given rise to much confusion. Properly speaking, the one includes the other, for all contagious diseases, that is to say, those communicated by direct contact with the patient or with fomites (as scarlet fever and smallpox), are infectious; but many infectious diseases that are spread through the agency of contaminated water or food (as typhoid fever and cholera), or by the bites of insects (as yellow fever and malaria), are not contagious, but are communicated from man to man indirectly.

Susceptibility.—When the exciting cause of an infectious disease either directly or indirectly communicable is introduced into a community, not all of those whose systems are invaded become stricken with the disease, even though they may receive the same dose of the organisms. Of a dozen children exposed at the same time and for a like period to a pre-existing case of scarlet fever, perhaps one, or three, or six, or none at all may be seized; of a hundred consumers of typhoid-infected milk, perhaps a dozen may be infected; in an entire community of a hundred thousand persons, all drinking water from a common supply, a few hundreds or thousands may be stricken with cholera in the event of extensive specific pollution of the supply, the rest of the population escaping with no symptoms whatever. The reason for this lies largely in differing susceptibility: one person may be very susceptible and others wholly resistant, regardless of the extent of exposure or of the number of exposures; some may resist a few exposures and later succumb. Some may be exposed without any resulting invasion. Whether or not a given individual will be attacked may depend also upon the number of organisms which enter his system; for while a few disease germs may be overcome and destroyed, a larger dose may secure a foothold and cause injury. On the other hand, what might be an overwhelming dose to one may be doubled and trebled, and yet be ineffective against another.

Susceptibility is influenced by a number of conditions, including age, race, family predisposition, cold, fatigue, etc. A person who to-day is insusceptible may, a few days hence, acquire susceptibility through any one of a number of causes which bring about a depressed condition of the system, such as lack of proper food, exposure to cold or extreme heat, exhaustion from overexertion, mental disturbance, loss of sleep, abuse of alcohol, overcrowding, mechanical injury, and constitutional disease. A person may carry virulent pneumococci in the respiratory tract and not be affected, because of the natural defensive properties of his cells; he may for the same reason escape an attack of Asiatic cholera, although large numbers of the specific organisms have gained access to his intestinal tract; and yet, in the former case, a bad cold, and in the latter, a derangement of digestion, may overcome his defence and he falls a victim.

An individual who is insusceptible to the influence of a particular pathogenic organism is said to be immune, or to enjoy immunity. Immunity may be either natural or acquired, and acquired immunity may be active or passive. Natural immunity is the inherent ability to resist

infection when the system is invaded by disease germs: for example, the insusceptibility of man to hog cholera and rinderpest; of carnivora to tuberculosis; of rats, dogs, and birds to anthrax; of horses and cattle to typhoid fever and cholera. In these and in many other instances that might be given, the respective organisms, on being introduced, find themselves opposed by conditions which are inimical to their existence and multiplication, and they soon succumb to the hostile influences. This form of immunity is, however, not always absolute: it can be overcome in various ways. Thus, while birds are naturally immune to anthrax, it has been shown that certain species may be rendered susceptible by starvation or cold; and rats lose their immunity to the same disease when they are fed wholly on a vegetable diet.

Acquired immunity is, as stated, of two kinds: active and passive. Active acquired immunity follows recovery from an attack of a disease which, except in rare instances, occurs but once in the same person (as yellow fever, scarlet fever, smallpox and chicken pox); or from a disease of an allied nature (as immunity to smallpox after cow pox); or it can be induced artificially by the injection of increasing doses of bacterial toxins or of bacteria which have been killed by heat or diminished in virulence. It can be acquired not only against diseases, but against certain proteid vegetable poisons (ricin and abrin) and snake venoms (rattlesnake); but it cannot be acquired against the numerous alkaloidal poisons. In but few diseases does one attack confer a lasting immunity; and even in these, second and even third attacks may sometimes occur, but their severity is, as a rule, much diminished; thus, smallpox and measles. With some diseases a single attack confers a temporary immunity (*e. g.*, pneumonia, la grippe, and diphtheria), but subsequent attacks may be of equal or greater severity. With other diseases, notably malaria, immunity may be acquired with such extreme slowness that increased susceptibility may appear to become established.

Passive acquired immunity is that which is brought about by the injection of serum obtained from the blood of an animal that has acquired an active immunity, the serum containing antitoxin; and it may be acquired also through the milk of an immune mother, the antitoxin being secreted therein. Passive immunity is acquired rapidly and with practically no danger or discomfort, but the protection conferred is only transient. On the other hand, active immunity is a matter of much less rapid appearance, but its protective influence is much more lasting.

The tolerance which the system develops toward a specific poison becomes established as a result of certain processes concerning which we have practically no actual knowledge. While we know that certain means employed produce certain results, the various changes which occur within the system during the process are matters concerning which thus far we can only theorize. We are met at the outset by the fact that protoplasm is a substance of extraordinarily complex composition, which defies exact analysis, and the products which it elaborates are, so far as we know, of equally complex nature. It combines with and

is acted upon by various materials, which, according to their nature, promote or disturb metabolism; *e. g.*, nutritive matters and toxins. It is with the latter that problems of immunity have to deal, for although under some conditions protoplasm is by them destroyed or disturbed in its functions, under others it is able not only to withstand their influence, but to develop antagonistic products, which overcome them completely and thus prevent disease or promote recovery.

All our knowledge of what occurs in the establishment of immunity and all the therapeutical applications based upon this knowledge we owe to animal experimentation of an exceedingly ingenious and interesting nature, which has given rise to several theories. Of these, the "retention theory" of Chauveau and the "exhaustion theory" of Pasteur have long since been disproved and possess now merely an historical interest; and the only ones which have withstood the test of time and investigation are the "humoral theory" of Ehrlich and the "cellular theory" of Metschnikoff, both of which will be considered below.

EHRLICH'S THEORY.

Ehrlich's humoral or side-chain theory, which had its inception in 1897, explains first the action of the soluble bacterial toxins and their antitoxins, then deals with immunity against these poisons and the bacteria which secrete them, and finally embraces the far more complicated question of immunity against those pathogenic organisms which liberate no soluble toxins, but bring about results which in some way are dependent upon the actual presence of the bacterial cell. The analogy between bacteriolysis and hæmolysis has made the experimental work much less laborious, since the latter can be employed to solve the problems of the former.

Toxins and Antitoxins.—In their interference with metabolism, different species of pathogenic bacteria act in very different ways; they produce different kinds of poisons whose actual nature is as yet but little known, and these interfere with the cell functions, each in its own manner. They appear to possess certain definite chemical affinities, like the far simpler inorganic compounds; they are precipitated by certain agents and redissolved by others; they combine with other complex compounds and form more or less stable inert substances. Whether the bacteria are within the tissues elaborating the poisons and sending them to distant parts of the body, or are grown in artificial culture media outside, the poisons which a given species produces appear to possess the same properties, so far as they can be studied.

Bacterial diseases may be divided into two classes: (1) those in which the infective agents are localized and produce their effects through soluble poisons which they secrete and send through the system in the blood stream; and (2) those in which, whether localized or not, the infective agents act not through soluble poisons, but in some manner dependent upon their actual presence in the tissues and yet not explainable in all cases by mere mechanical presence. These bacteria, however, contain

poisons united with their protoplasm—intracellular toxins, some of which have been separated and subjected to careful chemical analysis; and it may be that they become effective on liberation from the bacterial cells when these die and are disintegrated. Indeed, we know that, in the autolysis of cultures of *B. typhosus*, a toxin is liberated into the culture medium; and Vaughan and Wheeler [1] have obtained, in soluble form, highly poisonous material from the cell substance of colon, typhoid, and anthrax bacilli. That the last-named organism produces an intracellular poison was shown first by J. W. Vaughan,[2] all prior investigation having given negative results. Intracellular poisons have been demonstrated also by Detweiler [3] (*B. prodigiosus*, *B. violaceus*, *Sarcina lutea*, and *Sarcina aurantica*) and by Gelston.[4]

As examples of the first class may be cited diphtheria and tetanus; and of the second, the true septicæmias, in which the bacteria are distributed generally, and typhoid fever and pneumonia, in which the bacteria have a selective affinity for special organs. It is likely that in the establishment of immunity to both classes of disease, the general principles of the process are the same, although the details may differ.

In the diseases of the first class (diphtheria and tetanus), acquired immunity depends upon the formation, within the system, of substances termed *Antitoxins*, which, while having no power to destroy the causative bacteria themselves, neutralize their toxic products (toxins). In the immunizing process a very small part of what, under ordinary circumstances, would be a fatal dose of the specific toxin, or a small dose of a weakened toxin, is given subcutaneously to an animal, and this is repeated at intervals of a few days. After a time, the dose is increased, and eventually the animal is capable of receiving without injury a normally fatal dose, and is then possessed of an *active acquired immunity*. If now the animal be bled and its serum be injected into another, it will be found that the latter can resist infection by the organism which produces the toxin, or that if infected before treatment, the injection will exert a curative influence. In 1890 Behring made this discovery as to diphtheria, after he and Kitasato had found it to be true of tetanus. In 1891, Ehrlich, working with abrin and ricin, found that these toxins treated *in vitro* with the serum of animals immunized therewith became neutralized and incapable of causing injury.

The protection transferred from the actively immune animal to the other is *passive acquired immunity*. The serum of the immunized animal differs from that of the normal in that it contains the specific antitoxin, which is a substance believed, with good reason, to unite in a definitely chemical manner with the specific toxin to form an inert compound.

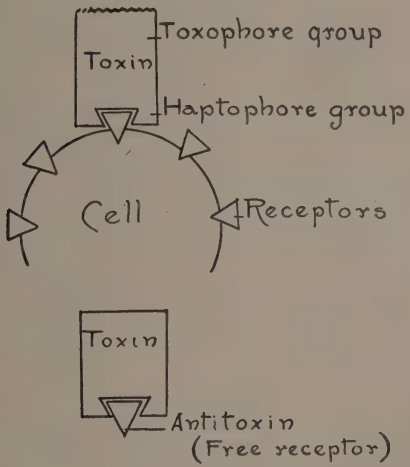
How the antitoxin is formed in the system is an interesting question, which Ehrlich explains in the following manner: The bacterial toxins have special affinities for special cells, and if they are introduced in

[1] Journal of the American Medical Association, September 3, 1904.
[2] Transactions of the Association of American Physicians, 1902.
[3] Ibidem. [4] Ibidem.

sufficient amounts those cells are destroyed; but if not, they are merely damaged by the union of the toxin with certain atom-groups of the cell for which it possesses the special affinity. The atom-group with which the toxin unites is called a *Receptor* or *Side-chain*. The cell, being damaged by the loss of this portion of its substance, proceeds to repair itself by replacing this receptor; but, following Weigert's law of supercompensation, it produces an excess of receptors, which, not being needed, are cast out into the blood stream, where they are free to unite with any fresh portions of toxin with which they may come in contact. These free receptors are the antitoxin.

The union of the toxin with the receptor of the cell or with the free receptor (antitoxin) is effected by an atom-group called the *Haptophore*. When the toxin becomes fixed to the cell by this group, it may proceed to destroy the cell by its poison molecule or *Toxophore;* but when it unites with the free receptor and thus satisfies its only attaching group,

FIG. 113.



its poison molecule has no cell upon which to work, and is consequently unable to produce harm. The receptor thus acts in two ways: it may attract the toxin to the cell, which thus may suffer, or it may protect the cell when it is no longer an integral part thereof. (See Fig. 113.)[1]

It has been shown by Ehrlich and others that a specific proteid toxin differs in one very important respect from alkaloidal and other common poisons, namely, that the latter are possessed of no haptophore groups with which they can form chemical combinations with the body cells or with substances derived therefrom. A dose of morphine, for example, no matter how frequently it is repeated, is incapable of causing the

[1] Figure 113 and the succeeding figures in this chapter are purely diagrammatic; and in order that no erroneous conception may be formed concerning the various substances which they represent, shapes have been adopted which are not likely to suggest actual cellular or molecular forms.

formation of a substance with which it can unite to form an inert body, although it can establish a tolerance for larger doses; in other words, no morphine antitoxin can be produced. If one should attempt to immunize an animal against morphine, the serum of that animal when mixed with a fatal dose of morphine would not deprive the latter of its power to poison another, as will an antitoxic serum mixed in proper proportion with a lethal dose of its corresponding toxin. Ehrlich says that the term *toxin* should be applied only to those toxic products of metabolism with which, by animal experimentation, one can obtain a specific antitoxin. As examples of true toxins may be cited those of diphtheria and tetanus, snake-venoms, abrin (from the jequirity bean) and ricin (from the castor bean). In the case of any one of these, a reaction occurs in the body, whereby the toxin becomes bound firmly to the cell, instead of entering into loose combinations which are easily broken up, as in the case of alkaloids.

It must not be supposed that the so-called receptors or side-chains are concerned merely with toxins and antitoxin formation. The cell protoplasm is an exceedingly complex substance and the cell is something more than a mere molecule: it is made up of many very complex molecules. It is unfortunate that attempts to explain immunity with the aid of diagrams lead many to conceive that the words *cell* and *molecule* are in a sense synonymous. The smallest possible drop of water consists of many molecules, all of the same character; but a cell is an aggregation of complex molecules of diverse natures and functions. The cell possesses certain atom-groups (receptors, side-chains) with affinities for nutritive materials which come within the range of their chemism, and through them it fixes within itself that which it needs for the carrying on of its functions. It possesses affinities also for the proteid toxins, which are believed to be similar to, though less complex in composition than, the nutritive materials. Doubtless, it possesses many other atom-complexes with other functions; and doubtless, also, the number of each kind is such that the destruction of a few does not necessarily mean the death of the cell, which under favoring conditions may proceed to make good its loss by processes of repair. The side-chains which are concerned in the fixation of toxins and which are cast off into the blood stream as antitoxin are denominated by Ehrlich *Uniceptors* or *Receptors of the first order*, being of the simplest kind and possessing a single bond of attachment, the haptophore group. Other more complicated receptors than these will be considered presently.

That the union of toxin with antitoxin is a purely chemical process, is believed by Ehrlich and most other investigators, and as proof are cited a number of facts. Thus, when a toxin is mixed with its corresponding antitoxin in proper proportions in a test tube, it becomes neutralized and is then incapable of acting injuriously any longer. Like acids and alkalies, the two can be titrated against each other. Again, as with most chemical reactions, the union of the two is hastened by warmth, and occurs more readily when concentrated solutions are employed. It appears, however, that with tetanus toxin, at least,

the union with antitoxin is at first a somewhat loose association, which can be disrupted ; and that, as time goes on, the combination becomes fixed. This has been shown in an interesting experiment by A. Wassermann, who, having found that a mixture of tetanus toxin and guinea-pig-brain emulsion possessed no toxic action for guinea-pigs, while mixtures with emulsions of other organs of the same animal retained their power, concluded that the toxin has a special affinity for the cells of the central nervous system, and that these contain normally the antitoxic side-chains, which are the same as those existing in the serum of an immunized animal. It is known that the tetanus toxin reaches the cells of the central nervous system through the motor axones, and that the antitoxin reaches them through the circulation. Wassermann injected some neutralized toxin into the hind-foot of a guinea-pig and saw no result. Next he injected some adrenalin into the hind-foot of another guinea-pig, and after this agent had caused the capillaries to contract he injected some of the same neutralized toxin, and the animal became tetanized. The circulation being stopped, the antitoxin could not reach the central nervous system, but the channel of absorption of the toxin was open, and the conclusion must be that the toxin broke away from its combination and was absorbed. On the other hand, when the mixture of toxin and antitoxin was allowed to stand some hours and was then injected into an animal after adrenalin treatment, no symptoms were produced, since firm union had become established between the two substances, and the toxin could no longer free itself.

Toxins are decidedly unstable, their strength diminishing with age. Ehrlich found that a single antitoxic unit saturated very variable amounts of different toxins, and that a neutralized mixture of one antitoxic unit and diphtheria toxin often required the addition of many minimum lethal doses (the amount necessary to kill a 250-gramme guinea-pig in 48 hours) of the toxin, in order to produce a fatal result. The combining power of the toxin was found to be unimpaired, but its toxic property had diminished, and from this fact Ehrlich concluded that the toxin molecule possesses two independent groups of atoms, one of which, the toxophore, is prone to undergo alteration of structure, while the other, the haptophore, remains unimpaired. To this degenerated toxin molecule Ehrlich applied the term *Toxoid*. By reason of the fact that the haptophores of the toxoids are unimpaired, an animal treated with toxoids can elaborate antitoxic substances, the toxoids attaching themselves to the cells in the same way as the toxins. Studying the degenerated toxins further, Ehrlich found in addition to *Toxones*, which are original products feebly toxic to the nervous system, a number of modifications possessing weaker affinities for antitoxin and for cells than those of toxins, but capable of combining with antitoxin and of producing slow poisonous effects, as, for example, paralysis. To these intermediate products he gave the name *Epitoxoids*. He found also other modifications which possess greater affinity for antitoxin than has toxin, and to these he gave the name *Prototoxoids*.

To still others possessing the same degree of affinity that toxin has for antitoxin he gave the name *Syntoxoids*. Further research by Madsen and Dreyer and Ehrlich has demonstrated the existence of *Toxonoids*, poisonous for one species but not for another, and of *Prototoxin*, *Deuterotoxin*, and *Tritotoxin*, possessing different affinities for antitoxin, and also *alpha* and *beta* modifications of each.

Through the fact that toxoids are unimpaired as to their haptophores, so that they can link themselves to the cells and yet cause no ill effects, Wassermann and Bruck were enabled to prove experimentally the increased production of receptors. They found that, using an old wholly non-poisonous tetanus toxin on a rabbit, they could get no antitoxin production, and this indicated either that the material injected could produce no physiological action, or that if it caused the proliferation of receptors they were not cast off by the cells into the blood. But they demonstrated that the toxoid did act, for the animal could withstand a normally fatal dose of the toxin, the toxoid having united with the cells to which the toxin would have linked itself. On waiting several days until the receptors began to be produced in overabundance, thus increasing the number of points of attachment, they found that the animal not only could not withstand a minimum lethal dose, but was killed by a smaller dose than is required to kill a normal animal. This showed that the receptors were produced, but not cast off; and being retained by the cells they gave the toxin an extra number of points of attachment through which to poison the cells, whereas had they been cast off they would have linked themselves to the toxin in the blood-stream and thus neutralized it. It appears, therefore, that, when the receptors are overproduced they require for their liberation some stimulus which the haptophore itself is incapable of supplying, and that, under ordinary conditions of immunizing with toxins instead of with wholly non-poisonous toxoids, this stimulation comes from the toxophore group.

A true antitoxic serum is obtainable only by injecting soluble toxins, and it happens that the only pathogenic bacteria that produce them to any considerable extent are those of diphtheria and tetanus, the others retaining their poisons in some form of combination with their protoplasm. The production of immune serums for the bacteria of the latter class requires the injection of the bacterial cells themselves, either living or killed, the latter being most often employed for the first injections. There is this very important difference between the serums obtained through the injection of toxins and those caused by the injection of the bacterial cells themselves: the former are antitoxic—they neutralize the specific poison; the latter are not antitoxic, but they act against the bacteria themselves. While the experimental work along the line of production of bactericidal serums has been enormous, and while our understanding of the processes which go on in the body is constantly growing, no such measure of success has yet been achieved as in the case of the diphtheria antitoxin.

Bacteriolysis.—In 1888, Nuttall discovered that normal serum and

various body fluids have the power to kill and dissolve various species of bacteria, and that this property disappears when the same are heated to 55° C. (131° F.) or allowed to stand for a week or more. This property was ascribed by Buchner, in 1892, to the influence of substances which he called *Alexins* (now known as *Complements*). The living animal has the same power when the organisms are injected in not excessive numbers. Thus, one can inject small doses of cholera organisms into a guinea-pig without causing any injury, and if the dose be gradually increased the animal becomes so resistant that it can withstand a single dose of many times the amount that, in an untreated animal, would inevitably cause death. In other words, the animal becomes immune to cholera; its system has undergone changes which enable it to destroy the specific organism in ordinarily overwhelming doses. If its serum is injected in very small amounts into other guinea-pigs, the latter also acquire the same immunity. It was shown by Pfeiffer, in 1894, that animals thus artificially immunized could receive without harm into their peritoneal cavities doses of cholera germs, which within 20 minutes would be dissolved by the peritoneal exudate; and he asserted that the result was due to a substance different from Buchner's alexins and produced in the body during the process of immunization. He showed also that a non-immunized guinea-pig, which would be killed by the intraperitoneal injection of a certain dose of cholera germs, could withstand the same if some *heated* immune serum (thus deprived of its complement) were introduced at the same time; and he concluded therefrom that the immunizing material, although it had been exposed to heat, had not lost its bactericidal property, and that it had influenced the organization in some way so that it could destroy the bacteria. Later, it was discovered by Bordet that the bactericidal power can be restored by the addition to the heated serum of a small amount of normal serum from a non-immunized guinea-pig, thus showing that, for the solution of the bacteria, two substances are required, one of which (complement) is a normal constituent of the blood, and the other (immune body) a substance called forth by the immunizing process. While the perfectly fresh immune serum, like fresh normal serum, has power to dissolve cholera organisms *in vitro*, so, too, on keeping, it loses it; but the addition of some fresh normal serum or of some peritoneal exudate restores the property; that is, it reactivates the inactive serum. This was shown by Metschnikoff and by Bordet (in 1896) prior to the beginning of experimental work in hæmolysis. It is thus evident that, with both normal and immune serum, two substances are involved in the process of bacteriolysis: one, the complement, is thermolabile (destroyed at 55° C.); the other, the immune body, capable of conferring immunity, is thermostable (resistant to heat).

Hæmolysis.—The abandonment of transfusion of blood was caused so long ago as 1869 by the fact that marked destruction of the red cells was found to occur, as was shown by the hæmoglobinuria which followed the operation; but transfusion can be practised without injury between animals of the same species and between certain animals closely

related, as, for example, between the dog and the wolf; but not between unrelated species, as the dog and rabbit, or the dog and horse. Rabbit serum will dissolve the red corpuscles of the horse, ox, pig, monkey, and man, but not those of the hare; guinea-pig serum acts against the corpuscles of rats and mice, but not against those of rabbits; human corpuscles are dissolved by the serum of the horse, monkey, ox, sheep, etc. Although transfusion was abandoned at the time and for the reason stated, the hæmolytic action of blood serum attracted but little attention until 1898, when it was shown by Belfanti and Carbone that the blood serum of horses which had been treated with injections of rabbit blood was poisonous to rabbits, while that of horses not so treated had no such property. Later, Bordet announced that guinea-pigs, after a similar course of treatment with rabbit blood, yield a serum which will dissolve the red corpuscles of a rabbit with great rapidity. The same solvent action was found to be exerted by the serum of other animals treated similarly with alien blood, and it was shown that it is a specific action; that is, that it is exerted (with certain few exceptions) only against the red corpuscles of the particular species whose blood is used for injection. In other words, if species A is injected with the blood of species B, A's serum will acquire the property of dissolving B's corpuscles, but not those of species C or D. This destruction of blood cells is known as *Hæmolysis,* and the agents which bring it about are termed *Hæmolysins.* The nature of the hæmolytic substance has been the subject of much investigation, which has proved that the solution is effected not by one single constituent of the serum acting alone, but by two acting together, each being powerless in the absence of the other. Ten years previously, in 1888, Nuttall had pointed out that many normal serums possess the property of destroying bacteria, and that this ceases on exposure of the serum to a temperature of 55° C. (131° F.). Investigating hæmolysis, Bordet found that in this process, too, the property disappears at this temperature, but can be restored by the addition of a very small amount of serum of another animal of the same species, that has not been subjected to treatment; that is to say, of a normal animal. Later, it was discovered that an inactivated normal or immune serum can be reactivated, not only by normal serum from the same species, but also by that of other animals not necessarily nearly related. Thus, goat serum, which is hæmolytic for guinea-pig and rabbit blood, loses this property on being heated to 55° C., but gains it again on the addition of horse serum, which itself has no action whatever on rabbit blood.

It was clear, then, that at least two substances are required in hæmolysis; one unable to resist exposure to 55° C., but existing in both normal and immunized animals, and the other, resistant to 55° and even 65° and 70° C., and existing only in the serum of those immunized. To the former, common to both kinds of serum, Bordet applied the term *Alexin,* invented in 1892 by Buchner for the bactericidal substances which Nuttall had shown to exist in normal blood; to the other, found only in the serum of the immunized animal, he applied

the term *Substance sensibilisatrice.* These terms and many others that have been coined as substitutes have been superseded respectively by *Complement* (Ehrlich) and *Immune body* (Pfeiffer) or *Amboceptor* (Ehrlich). The actual solvent substance is the complement, but it cannot act unless the immune body (amboceptor) prepares the red corpuscles through some means of its own, fixing itself, according to Ehrlich and Morgenroth, in the red cells themselves. The complement is not only less resistant to heat than the immune body, but is less persistent on storage of the serum. Investigation by Ehrlich and Morgenroth of the power of normal blood serum to dissolve alien corpuscles demonstrated that this, too, does not depend upon a single substance, as was maintained by some, but upon two substances acting together, as had been proved to be the case with immune serum. The second substance analogous to the immune body is now known as the *Interbody*, *Go-between*, or *Zwischenkörper.* Ehrlich and Morgenroth proved also that a normal serum which will destroy the red cells of more than one animal species possesses an interbody for each species, and different complements as well.

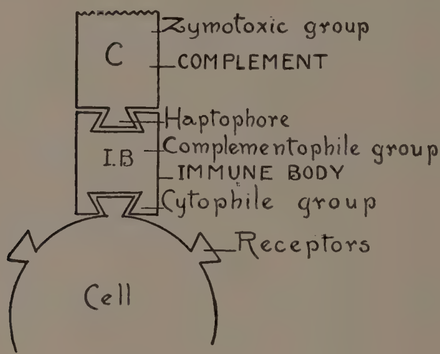
A hæmolytic serum is intensely poisonous to the animal species whose blood has been employed in its production, injections of a few cubic centimetres causing destruction of the blood cells *in corpore.* It acts like a toxin, and similarly an artificial immunity to its action can be produced, an antihæmolysin being formed instead of an antitoxin.

In attempting to discover the relationship of the active constituents of hæmolytic serum to the blood-cells which it dissolves, and to determine upon what its specific action depends, Ehrlich and Morgenroth had recourse to a most ingenious experiment, by which they proved that the immune body combines with the corpuscles, and that the combination is of a chemical nature and resists attempts to break it apart.[1] The specificity of the union was shown by the fact that the combination does not occur when blood is used other than that for which the serum is hæmolytic. They proved also that a similar combination between the blood corpuscles and complement does not occur, and that the immune body possesses two affinities; one, very strong, for the corpuscle, and one, less strong, for the complement. Since the latter, as proved, has no combining affinity for the red corpuscle, its action must be dependent upon the interposition of some agent which has; and this is the immune body, with its two combining groups. Therefore, it is plain that the function of the immune body is to enable

[1] They destroyed the complement of a goat serum that was hæmolytic for sheep blood by heating it for a half-hour at 55° C., then added 4 volumes of a 5 per cent. mixture of sheep blood in 0.75 per cent. salt solution, and after letting the mixture stand for 15 minutes at 40° C. they caused all the corpuscles to separate as a sediment by centrifugation. That none of the immune body was present in the supernatant fluid they proved by adding to the latter some more sheep blood and normal serum (containing complement) and finding that the corpuscles were not dissolved, as they would have been in the presence of the immune body. The sediment of corpuscles which had combined with the immune body was mixed with normal (complement-containing) serum, and after a time the corpuscles were dissolved.

the complement to attack and dissolve the corpuscle, and this it does by acting as a coupling-link between the two. Its rôle is the same in bacteriolysis, binding the complement to the bacterial cell in the same way. Diagrammatically, it may be shown as in Figure 114. It will be seen that the same relations exist between the immune body and the blood corpuscle or bacterial cell as between a toxin and its antitoxin. Both the immune body and the antitoxin possess haptophores, which fit respectively the receptors of the blood corpuscle and the haptophore of the toxin. They are analogous products—free side-chains.

Fig. 114.



The importance of the study of the phenomena of hæmolysis lies in the fact that analogous, if not identical, processes occur in bacteriolysis; and it happens, too, that experiments with blood cells are more simple and convenient in several respects, among which is the fact that they can be carried out *in vitro*, and they are also better adapted to accuracy. Although the study of bacteriolysis antedates that of hæmolysis by ten years, it is to the latter that our knowledge of immunity is especially due.

The side-chain theory, which originally applied to the production of specific antitoxins and was then extended to the formation of specific bacteriolysins and hæmolysins, was finally broadened so as to apply as well to the production of all other antibodies of whatever nature caused by the introduction of any substance which can combine with receptors in the body and bring about the overproliferation and setting free of the same. It is not to be supposed that the body cells are of such simple structure that they have affinities for only nutritive materials, toxins, alien bloods, and pathogenic bacteria. As has been pointed out, the living cells are enormously complex aggregations of exceedingly complex molecules, and Ehrlich holds that the atom-complexes have a great diversity of functions and combine with whatever substances, and only those, for which they have receptors; and these substances naturally must possess atom groups (haptophores) which can link themselves to the cell receptors. The haptophores of the immunizing substances are quite distinct from the atom complexes which

have functional peculiarities; for example, the toxophore groups of toxins, and the zymophore groups of ferments.

Illustrative of the complex nature of body cells and of the multiplicity of atom groups which they possess, may be cited the production of various other cytotoxins.[1] Thus, the injection of alien spermatozoa causes the production, in the serum of the animals injected, of specific substances termed *Spermotoxins*, which have the power to immobilize, if they do not dissolve, the spermatozoa of the species from which they are derived, and also to hæmolyze its red corpuscles. Again, in the same way, a serum can be obtained by injection of ciliated epithelium from the trachea of the ox which will have a similar action on this form of cells, and this serum also is hæmolytic (*Trichotoxins*). By injecting material from the central nervous system, from the liver, from the kidneys, from the mesenteric glands, and from bone marrow, specific serums have been obtained which are poisonous respectively to the nerve cells (*Neurotoxins*), liver substance (*Hepatotoxins*), kidney substance (*Nephrotoxins*), and leucocytes (*Leucotoxins*). Each of all these possesses a thermolable complement (destroyed by exposure to 55° C.) and a thermostable immune body. But this is not all. The study of the production of antibodies has gone much farther, and it has been proved that, proceeding in the same way as in immunizing animals against toxins, a variety of antibodies can be produced. Thus, by beginning with very small doses of specific hæmolysin and gradually increasing the amount of the injection, an antihæmolytic serum can be produced, which, when added to the hæmolytic serum, will inhibit the latter's action. Investigation has demonstrated the existence in antihæmolytic serums of anticomplement and anti-immune bodies, both of which are specific. In the same way can be produced antispermotoxins, antileucotoxins, and even antibodies to these antibodies. An enormous amount of research work of a most complicated and ingenious nature is going on constantly, having for its object the solution of the many problems of immunity, and these few facts are given merely as examples, for a general survey of the subject in all its branches is beyond the scope of a work of this nature, particularly until a wider practical application can be made of the numerous discoveries.

Complements.—The elements of blood serum, which, through the intermediation of the immune body, bring about the destruction of alien blood cells or bacteria, are not produced as a result of an immunizing process, but are normal constituents of the blood. As stated elsewhere, Ehrlich has demonstrated that the blood contains not one, but a multiplicity of complements, and that they may differ in their resistance to heat. Thus, the serum of a goat immunized with sheep blood lost, on being heated to 55° C., the power which it possesses normally to dissolve rabbit corpuscles, but was hæmolytic for sheep

[1] "*Cytotoxin* is used for any substance in serum, venom, or bacterial cultures, or of plant origin, which destroys cellular elements, either animal or vegetable. The hæmolysins and other toxic substances which kill but do not dissolve cellular elements are included under Cytotoxins, also the bacteriolysins (bactericidal substance, alexin)." Nuttall, Blood Immunity and Relationship, p. 14.

blood until it was heated to 65° C. Most complements, however, are destroyed at the former temperature. The multiplicity of complements is, however, a matter of disagreement between Ehrlich and Morgenroth and others, on the one hand, and Gruber, Bordet and their followers, on the other; but the weight of experimental evidence appears to be with the former, who maintain that a different complement is required to link itself to immune bodies that are specifically hæmolytic for different kinds of blood corpuscles.

Complements are believed to exert a sort of digestive fermentative action upon the cells (blood or bacteria) to which they are linked by the immune body. They lose this property, as a rule, when they are heated to 55° C. They are believed to contain two important atom complexes: one, the haptophore, with an affinity for a similar group in the immune body; the other, the zymotoxic group, is the functional (digestive) part. It is the latter that is affected by exposure to 55° C., the former still possessing the power of combining with the immune body and of stimulating the production of anticomplement when the heated normal serum is injected. Complements that have been deprived of their zymotoxic groups are analogous to toxoids, and are known as *complementoids*.

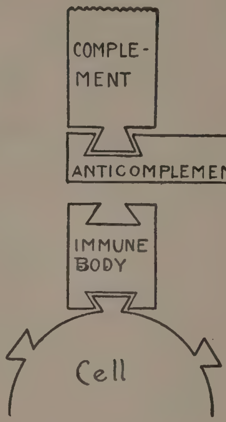
An immune serum, while it acquires a large amount of immune body, does not, as a rule, gain any additional amount of complement; and inasmuch as the two work together, it cannot exert its full power in test-tube experiments without the addition of a sufficiency of complement, which can be supplied in such experiments by the addition of normal serum. In the practical therapeutical application, however, of a bactericidal serum, the necessary complement may exist already in the blood of the patient; and inasmuch as such a serum may contain many thousand times as much immune body as complement, it follows that a relatively small dose will be sufficient to furnish an enormous number of linking bodies to enable the complement of the blood to perform its office; but, as will appear, there may be an insufficient supply of complement for the attainment of the desired result, and in practice the deficiency cannot easily be made up. Moreover, an excess of immune body, as also will appear, may act to the disadvantage of the subject. (See page 746.)

As to the source of the complements, there is considerable disagreement. By some they are believed to be secretory products of the leucocytes and of other kinds of cells, many of which have been shown to have phagocytic properties; Metschnikoff believes that they are not secretory, but decomposition, products of the leucocytes; Pfeiffer and others believe that the leucocytes are in no way concerned in their production, and Wassermann asserts that these are practically their only source.

While the process of immunization appears to have no influence in increasing the amount of complement, it is doubtless the case that their amount in normal serum is subject to more or less fluctuation in the same individual from day to day under varying conditions of health

and disturbance of the body functions. Thus, Ehrlich and Morgenroth have proved the disappearance of complement in poisoning by phosphorus, and Metschnikoff its diminution following suppuration. It is possible that reduced resistance to infection may depend upon the reduction of complement by the spontaneous production of anticomplement in the system. Although this spontaneous production has not yet been demonstrated, it has been proved by Wassermann that the injection of anticomplements increases susceptibility to infection. Anticomplement can be produced (Bordet) by injection of complement (normal serum of another species), thus causing the production of a serum which is antagonistic to hæmolysis and bacteriolysis, since the anticomplement possesses a haptophore group, which links itself to the corresponding group of the complement and thus prevents a similar union of the complement and immune body. This action is shown diagrammatically in Figure 115.

Fig. 115.



Except in those cases in which the complements of the two species possess identical combining groups, the anticomplements are specific bodies; that is, they combine only with their specific complements. The union of complement and anticomplement is very firm, as has been shown by Bordet, who found that it cannot be broken up by heat.

Immune Bodies.—The immune bodies, believed by the Ehrlich school to originate through the saturation of some particular atom complexes (side-chains) of some particular cells, are specific bodies; for example, that which links complement to one kind of blood cell will not act for that of another species; that which makes possible the destruction of a cholera germ will exert no action against the bacillus of typhoid fever. That they exist in one form and another in the system under normal conditions is generally admitted, for in the normal metabolism of the cells it is assumed that various substances—nutritive substances, for example—stimulate the overproduction and liberation of side-chains, among which may be some that are identical with those which originate in consequence of the introduction of alien bloods, bacteria, and other foreign substances.

Whether each immune body is a single definite substance or a combination of substances having special affinities for different materials is a matter in dispute, the former view being held by Bordet and Metschnikoff and the latter by Ehrlich and Morgenroth, who bring forward certain experimental proof of the correctness of their view.

It has been shown that different kinds of blood cells possess some similar receptors, and that each cell appears to have these atom complexes in great variety, so that a given cell may be able to link itself to the receptor of this or that immune body and not to that of some other;

and Ehrlich and Morgenroth regard the immune body of a serum as the sum total of its affinities for different cells, each corresponding to one *partial* immune body. A particular kind of blood cell or species of bacteria introduced into an animal's system may or may not find corresponding receptors for each of its many different combining atom complexes or haptophores. If it should not find them, then only a part of the possible number of partial immune bodies will be produced by the animal. In another species of animal, other receptors may be, and are, present; and in consequence the immune bodies produced by the two must differ to some extent in their composition, each containing certain atom groups or partial immune bodies that the other lacks, and each differing in similar respects from those produced by other species of animals subjected to the same and to different stimuli. If Ehrlich and Morgenroth are correct—and the weight of experimental evidence appears to indicate that they are—the employment of bacteriolytic serums made by combining a number of serums derived from different species of animals ought to give better therapeutical results than one derived from one species, and hence containing a smaller assortment of possible combining groups. The greater the variety of these groups, the greater the possibility for the human system to bring its complements into action; and these cannot exercise their functions unless they find the necessary intermediary agents—the immune or *partial* immune bodies. Indeed, it appears certain that in many experiments with lysins a number of different immune bodies or partial immune bodies are concerned. Inasmuch as the atom complexes or combining groups of the molecules that make up the bacterial cell may not be absolutely alike in different races of the same bacterial species, it is reasonable to believe that an immune serum produced through the employment of one particular culture will not affect all different cultures of that organism equally. In fact, that is what often is seen in actual practice: a bactericidal serum is active in a certain number of cases and of no value in others. Hence, as pointed out by Wassermann,[1] the way out of the difficulty is to employ, not a single culture, but a number of different cultures of the same bacterium in the preparation of a serum, in this way securing a very large number and variety of partial groups. Such a serum Wassermann would call *multipartial.*

In the same way that anticomplement can be produced by the injection of normal serum, so, also, can one bring about the formation of anti-immune body by injecting an immune serum into an animal in small and gradually increasing doses, after the method followed in immunization. The resulting serum will contain both anti-immune body and anticomplement.

Agglutinins.—It was observed so long ago as 1869 by Creite, and in 1875 by Landois, that the blood serum of an animal when mixed with the red corpuscles of many other species causes them to come together in clumps. In his experiments in hæmolysis, Bordet observed that in a hæmolytic serum this property is increased; that the agglutination

[1] New York Medical Journal and Philadelphia Medical Journal, October 15, 1904.

precedes the solution of the cells; and that the increase in agglutinating property is specific—that is to say, it is increased with respect to the kind of blood corpuscles that have been employed in the process of producing the hæmolytic serum, and also to some extent for that of closely related species. The substance which brings about this phenomenon is called an *Agglutinin.* It is not destroyed by exposure to 55° C., and it may resist even 70° C.; and so a hæmolytic serum which has been heated to that temperature, while it loses its hæmolytic property, is still capable of causing agglutination. The exciting cause of its genesis is supposed to reside in the stroma of the injected corpuscles. According to Stewart,[1] the injection of the stroma of an alien blood stimulates the production of agglutinins, while the cell contents stimulate more especially the production of hæmolysins.

The same agglutinating power is possessed by some normal serums for bacteria, and similarly it is specifically increased in bacteriolytic serums. The agglutination with which we are most familiar is that which is employed as a means of diagnosis in suspected typhoid fever —the Gruber-Widal reaction. The serum of a person ill with that disease, diluted with bouillon and mixed with a culture of typhoid germs will cause the latter to clump together. This happens whether the bacilli are living or dead. The agglutinin may persist in the system for many months or years after an attack of typhoid fever, suggesting a persistence also of the specific bacilli, which we know to be often the case, since they may be discharged in the urine continuously for many months after recovery.

The bacterial agglutinins were studied first by Gruber who concluded that in some way they affect the bacteria, so that they can be killed and dissolved; but experimental evidence tends to show that they are not necessarily injured, and that, on the contrary, they can even continue to multiply, even though agglutinated. It has been shown by Bordet and Malkoff that the bacterial agglutinins and the hæmagglutinins combine with the bacterial cells or blood cells in the same way as the go-betweens (Zwischenkörper) of normal serum.

The agglutinins are complex substances possessed of haptophores, which combine with haptophores in the blood cells and bacteria, and other atom groups which cause the clumping. The cells upon which they act (blood corpuscles and bacteria) contain what is called "agglutinable substance," which also is made up of at least two atom complexes, one of which is a haptophore, as mentioned above, and the other is sensitive to the atom group which causes the clumping. Thus, the phenomenon of agglutination is analogous to the chemism of hæmolysis and bacteriolysis; but the one is apparently not dependent upon the other, for hæmolysis and bacteriolysis may occur without agglutination, and agglutination may occur without subsequent solution. Thus, dog serum will agglutinate but not destroy anthrax bacilli, and rat serum will destroy but not agglutinate them.

[1] American Journal of Physiology, XI., No 3., June, 1904, p. 250.

Ehrlich regards the agglutinins as special products in an immune serum, analogous to the bacteriolysins and hæmolysins.

The atom complex that causes agglutination is very susceptible to the action of acids and other substances, and when it is deprived of its functional power, the result is the same as with toxins that have lost their toxophore groups: the agglutinin retaining its haptophore group is converted to an agglutinoid, just as a toxin becomes a toxoid; it still can combine, but it cannot agglutinate.

Precipitins.—If the serum of one species of animal be injected into an animal of another not closely related species, the serum of the latter will acquire the property of precipitating part of the proteid material of that of the former when the two are mixed together. For example, if we mix normal rabbit serum and horse serum, we observe no reaction; but if we inject a rabbit with horse serum at proper intervals, after a time its serum will acquire the property of causing a precipitate when it is mixed with horse serum. The substance which is developed in this process of immunization and which brings about the reaction is known as a *Precipitin.* Precipitins are not wholly specific in their action. A serum obtained by immunizing with the serum of species A may precipitate the latter and also that of some other closely related species. This was pointed out first by Nuttall,[1] whose extraordinarily extensive researches, conducted with hundreds of different kinds of blood and involving the making of many thousands of tests, have been very rich in results valuable alike to students of zoology, physiology, and immunity, and also to those who have to do with medico-legal investigation of suspected blood stains.

Precipitins have been found in certain normal serums. Thus, ox serum will precipitate that of man and also that of a number of other species, and the same is true of the serum of dogs, goats, and other animals. They have been found also in the serum of animals immunized with bacterial cultures; these are known as bacterio-precipitins, and are specific for the culture filtrates of the germs employed and for solutions of the material within the bacterial cell.

Precipitins, like agglutinins, are far more resistant to heat than the other immune substances, their functional property being not completely destroyed under 70° C. They combine in a definite chemical way with the substances precipitated, but the reaction is prevented by acetic acid. They are believed to contain two essential atom groups: one, unstable and functional; the other, a stable combining (haptophore) group. Precipitoids analogous to agglutinoids are known.

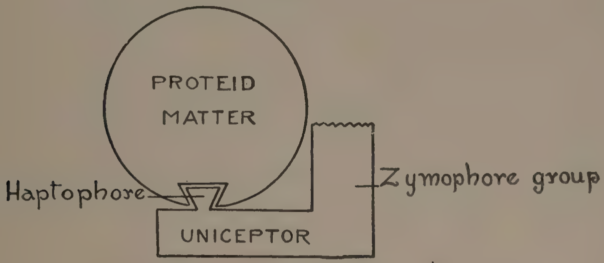
There is another form of precipitin, called *Coagulin*, which is developed in the process of immunizing animals with other albuminous substances. Thus, by employing milk, there is developed an immune body that will coagulate milk of the same kind as used. These lactoserums are, in some instances, also specifically hæmolytic and spermotoxic.

The agglutinins and the precipitins are more complex than the

[1] Blood Immunity and Blood Relationship, Cambridge, 1904.

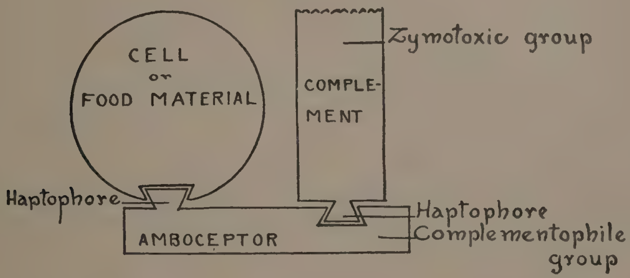
toxins and less so than the hæmolysins and bacteriolysins. Ehrlich conceives of the individuals of this group of immune substances as possessed of two atom-complexes, one of which, the haptophore, holds the substance acted upon, and the other, the zymophore, exerts a fermentative action which brings about the change. (See Fig. 116.) They are called by Ehrlich *Receptors of the second order*. The receptors of the first and second orders are known also as *Uniceptors*.

FIG. 116.



The immune bodies concerned in hæmolysis, bacteriolysis, and other lyses are more complicated than the antitoxins (receptors of the first order) and the precipitins and agglutinins (receptors of the second order). In this third kind, one haptophore group fixes the bacterium, blood cell, epithelium cell, food material or other substance concerned by the corresponding group in the latter, while another haptophore, represented usually as another arm, links to itself the complement

FIG. 117.



through the mutual attraction of the complementophile (haptophore) group of the immune body and the haptophore group of the complement. Both are held separately by the same kind of affinities, and the complement can proceed to exercise its digestive function upon its companion in captivity. This is shown diagrammatically by Figure 117, in the use of which and of the others presented in this chapter, it must be borne in mind that the action is not mechanical, but purely chemical, and that the figures are mere diagrams and represent bodies which never have been seen. Figure 117 is but another way of expressing the same idea as Figure 114.

The immune bodies of this class are known as *Receptors of the third order*. When they are formed and thrust out like the antitoxins into the blood stream in consequence of some immunizing process, they are known as *Amboceptors*; and those which are not so caused, but exist normally in the serum, are termed *Intermediary bodies, Zwischenkörper*, and *Go-betweens*.

From the fact that all receptors of whatever order possess haptophore groups, Ehrlich calls all free receptors *Haptins*. There are doubtless many more varieties of haptins than have yet been conceived of, and an infinite number of sub-varieties of each kind.

Metschnikoff's Theory.

Metschnikoff's theory of Phagocytosis, which dates back to 1884, holds that bacterial invasion of the system is followed by either attraction or repulsion of the leucocytes and other phagocytic cells by the bacteria, which in the former case become absorbed and destroyed. In case the phagocytes are repelled, or if the attraction is only partial, so that some bacteria escape, multiplication of the invaders occurs, with consequent lesions. The property of being attracted or repelled is known as *Chemiotaxis*, which is respectively positive or negative. In case of natural immunity, the chemiotaxis is positive and the cells move toward the bacteria and englobe them; in susceptibility, it is negative or only partially positive, or the phagocytes may not possess the requisite phagocytic power. In the acquirement of immunity, the negative chemiotaxis is converted to the positive form by the introduction of very small numbers of the specific bacteria or of weakened cultures, which bring about a tolerance on the part of the phagocytes, which eventually are enabled to attack and destroy the organisms in numbers which ordinarily would cause death. The phagocytes include the mononuclear and polymorphonuclear leucocytes, certain cells in the serous cavities, connective-tissue spaces, lymph nodes, neuroglia, splenic pulp, and in the lining of small bloodvessels, and elsewhere; but those chiefly engaged are the leucocytes.

The destruction of bacteria by the phagocytes is attributed to the presence of digestive ferments, which Metschnikoff calls *Cytases*, and which in their function correspond to the complements of Ehrlich.

Metschnikoff believes that what the Ehrlich school calls immune bodies and complements are produced within the phagocytic cell, and that, in natural immunity, they are retained within the cell; while in the artificial form, the immune body, but not the complement, is liberated into the plasma. He explains the presence of the two substances in an immune serum as a consequence of disintegration of phagocytes (*Phagolysis*); but Wassermann has demonstrated that complement exists naturally in the free state in the blood. He believes that under ordinary conditions the bacterium is englobed by the cell, which produces both substances necessary for the process of destruction. In what is known as "Pfeiffer's phenomenon" (see page 733), Metschnikoff asserts

that the phagocytes are broken up in consequence of the operation on the animal, and thus the cytase (complement) is liberated; but this alleged phagolysis is denied and disproved.

The Metschnikoff school asserts that not only the process of bacteriolysis, but also that of hæmolysis, is carried on by the leucocytes; that they also absorb and destroy the soluble toxins; that anticomplements do not neutralize complements, but merely paralyze the leucocytes; and that the circulating blood has no bactericidal power.

Both the Ehrlich and the Metschnikoff schools agree that, in acquired immunity, two substances, immune body and complement, are necessary; the former insists that these exist in a free state in the blood; the latter, that they are contained within the phagocytic cells. Both agree that the immune bodies are wholly specific, but the Metschnikoff school insists upon two common complements (*Macrocytase* and *Microcytase*). The Ehrlich school recognizes the importance of the leucocytes, but does not agree as to their rôle.

Practical Applications of the Results of Studies in Immunity.

While it is true that, in spite of the vast amount of experimentation on the subject, the practical application of what has been thus far discovered to the prevention and cure of disease has made comparatively little progress, it must be borne in mind that the problems of biochemistry are exceedingly complex; that the work of solving them is of quite recent origin; that the pursuit of methods for their solution has necessitated the investigation of many points of apparently indirect relation to the main question; and that one is obliged to reason largely from phenomena which are the outcome of processes which do not occur in nature. It may be said that the whole subject is still in its infancy, and that only a small part of the foundation of the final structure has yet been laid. Thus far the only really brilliant results achieved in the practical application of the discoveries in immunity are limited to one disease—Diphtheria—the toxic material of which, being soluble and extracellular, makes easily possible the production of an immune serum which can be used either as a prophylactic or as a curative agent. The pathogenic organisms other than those of diphtheria and tetanus retain their toxins within their cell substance, and the immune serums produced by their introduction into living animals are not antitoxic, but bacteriolytic, and exert only temporary protection and but slight curative action.

The lack of success in the treatment of diseases caused by this class of bacteria is due probably to the disparity in the amount of amboceptor and complement in the immune serum. As has been pointed out, a bacteriolytic immune serum contains an enormous increase in the amount of specific amboceptor (sometimes 100,000 times as much), but no increase in complement. Inasmuch as the conjoint action of both is necessary for the destruction of the bacterial cells, it follows that, unless the patient can furnish the necessary amount of complement,

the treatment must fail. To supply the needed additional complement is not an easy matter, even if normal serum be injected, on account of the multiplicity of complements; for, according to Ehrlich and Morgenroth, each kind of amboceptor requires a different specific complement; and hence they recommend the immunization of different species of animals with the same kind of bacteria and the utilization of a mixture of the several serums, thus bringing into action amboceptors and complements which, although differing according to the species in which they are produced, are, nevertheless, specific against the same organism, and some of them, at least, may satisfy the needs of the human system. Not only does a deficiency of complement in itself present an insuperable obstacle to successful treatment, but the excess of amboceptor may also work injuriously by preventing the available complement from exercising its function, as has been shown by Neisser and Wechsberg, who proved that it may unite directly with the complement, which has a greater affinity for free amboceptor than for that which has linked itself to the bacteria; whereas, in the absence of an excess, the complement will unite with that which already has engaged the bacteria. Thus it happens that successful treatment depends upon the very difficult problem of bringing together in the diseased system the proper amounts of amboceptor and complement to cope with the specific bacteria. An excess of complement is not to be thought of, but a material excess, either of amboceptor on the one hand or of specific bacteria on the other, is fatal to success.

DIPHTHERIA.

As has been stated, the disease in which the most brilliant results have been achieved in the application of an immune serum is Diphtheria, against which the agent may be employed either as a means of cure or as a prophylactic. Its introduction as a curative agent, in 1894, met at first with much adverse criticism, but its value was soon firmly established, and statistics of cases to the number of hundreds of thousands testify that the mortality has been reduced from about 40 per cent. to about 15 per cent. or lower. The statistics of the Boston City Hospital show that of 3067 cases treated during the period 1888–1894, 43 per cent. resulted fatally; while with antitoxic treatment the death-rate of 14,910 received during the period 1895–1904 was but 11.84 per cent. During the year ending December 31, 1904, the death-rate was 9.57 per cent., and if those cases which ended fatally within twenty-four hours of admission are eliminated, this figure is reduced to 6.95 per cent. Preventive treatment has been practised extensively in schools, hospitals, and other institutions for children, but the immunity thus conferred is but transient. In a children's hospital in which an outbreak of diphtheria occurred, Lohr[1] immunized 460 inmates and the outbreak was checked, no cases occurring within three weeks of the operation. Later, a few cases occurred, which illustrated

[1] Jahrbuch für Kinderheilkunde und physische Erziehung, September, 1896.

the temporary nature of the immunity. Of 99 patients with measles, treated because of the special danger of diphtherial supervention, not one was attacked. Similar outbreaks in children's institutions have repeatedly been checked, but since the protection conferred is so transient, reappearance of cases is likely to occur, as in the instance cited; and to guard against this, it is advisable to remove the inmates long enough to give the premises a thorough disinfection.

According to Netter,[1] immunity begins after 24 hours and wears off within 3 or 4 weeks. He recommends that, when a case of the disease occurs in a school, hospital, or other institution for children, the other inmates be treated. The treatment is advised also in measles and scarlet fever wards as a preventive of possible diphtherial complication. An instance is given in which the disease was a frequent complication in a measles ward, 2 to 4 cases occurring during each of 4 months, and 19 in the next succeeding 6 weeks, after which period each child was treated on entrance and no further cases occurred. The employment of the immunizing treatment as a routine practice is advocated by Caillé[2] for young schoolchildren, for the purpose of preventing primary infection and diphtherial complication of scarlet fever and measles. He recommends two treatments during the school year.

The serum employed acts upon the toxins, but it is not bactericidal, and hence does not act upon the bacilli which secrete them; but Wassermann[3] has brought to notice a serum which acts upon the bacilli themselves. It is the result of the inoculation of the specific bacilli in large numbers, rather than of the toxin, and causes changes in the intracellular substance of the bacilli, and agglutination. Schwone having shown that such a serum obtained by the inoculation of a single culture acts upon only a limited number of other cultures, the experiment was tried of treating the same animal with a large number of cultures, and in this way there have been obtained "multipartial" serums which agglutinate all cultures subjected to their action. Wassermann has made the important discovery that with such a serum it is possible to overcome the bacilli that so often remain for a long time in the nasopharynx, and thus prevent the patient from being liberated from house quarantine. A strongly agglutinating serum is evaporated to dryness *in vacuo*, mixed with sugar of milk, and made into tablets, which on being dissolved in the mouth confer upon the fluids of the same the property of agglutinating the bacilli, which then can be removed by spraying or gargling. A tablet is dissolved every two hours, and after fifteen minutes the clumped bacteria are removed by the spray or gargle. By this treatment the nasopharynx has in many cases been freed from the bacilli within a few days.

[1] Bulletin de l'Académie de Médecine, March 18, 1902.
[2] Archives of Paediatrics, October, 1903.
[3] New York Medical Journal and Philadelphia Medical Journal, October 15, 1904.

TETANUS.

Like diphtheria, tetanus is due to extracellular toxins which are produced by the localized bacilli. They are conveyed in the blood stream to the cells of the central nervous system, for which, as has been shown, they have a selective affinity, and with which they form a very close union. Although it is possible to produce an antitoxic serum which, in test-tube experiments, acts equally well with the diphtheria antitoxin in neutralizing the specific toxins, the antitoxic treatment of the disease has failed signally in fulfilling expectations. This is because before the diagnosis can be established, the injury to the cells has been effected beyond the possibility of repair. The antitoxin is, however, valuable in aborting possible attack, and its injection has become a routine practice in cases of gunshot wounds and similar accidents, especially after the annual observance of Independence Day.

HAY FEVER.

In hay fever we have a true intoxication, but the toxin is not of bacterial origin. The discovery of the cause of this exceedingly annoying condition is due to the investigations of Professor William Dunbar, of Hamburg, who proved that the disease is due not to bacteria, but to the poison contained in the pollen grains of various grasses. In his first communication [1] he showed the difference in the way susceptible and non-susceptible persons react to the dissolved toxin; 9 of the former subjected to its influence developed typical symptoms, and 20 of the latter were in no way affected. In a later paper [2] he showed that the autumnal catarrh, which is peculiar to this continent, is caused by the pollen of goldenrod, ragweed and other weeds not indigenous to Europe. In the same way that diphtheria antitoxin is produced, Dunbar obtains a horse serum which neutralizes the pollen toxin completely. This toxin is so powerful that one-forty-thousandth part of a milligram (corresponding to 2 or 3 pollen grains) is sufficient, when placed in the conjunctival sac of a susceptible person, to cause an attack lasting several hours, but it will yield readily to the antitoxin. Although the toxin of the grass pollens differs from those of the pollens of goldenrod, ragweed, etc., the grass-pollen antitoxin neutralizes them all. Statistics collected by various writers abroad and in this country show most favorable results of treatment. Unlike diphtheria antitoxin, Dunbar's preparations (liquid and powdered forms) cannot be employed subcutaneously, but are applied locally. The serum, evaporated to dryness and converted to a fine powder with sugar of milk, is administered as a snuff in very small doses. It does not confer lasting immunity, and must be resorted to during the season at intervals of a day or two, or, if the outdoor air be unusually rich in pollen, at intervals of a few hours. For application

[1] Deutsche medicinische Wochenschrift, February 26, 1903.
[2] Berliner klinische Wochenschrift, June 15, 22, and 29, 1903.

to the eyes, the serum itself is preferred. It is said that in the majority of unsuccessful cases either the antitoxin is not used sufficiently often or is taken in excessive amounts, which aggravate the difficulty. In some cases the mucous membranes are in such swollen condition as not to permit absorption.

DYSENTERY.

The exciting causes of dysentery (Shiga's and Kruse's bacilli) elaborate toxins which appear to be approximately identical, and which can be used for the production of antitoxic serums. Shiga claims for his serum a diminution in mortality amounting to about 50 per cent. Rosenthal [1] isolated a toxin from bouillon cultures of the bacillus, with which he succeeded in obtaining an antiserum, which is said to have had about the same measure of success that Shiga claims. The extensive researches made in this country during 1903 and 1904 into antidysenteric serum have led to the conclusion that it is not a success.

TYPHOID FEVER.

Numerous attempts have been made to produce an antityphoid serum for the treatment of the disease when it has become established, but as yet the results have been very disappointing, although Chantemesse [2] claims that in the treatment of 765 cases with his serum during a period of three and a half years, a very low mortality has been observed. During the same period, the cases treated in other Paris hospitals yielded an average mortality of 18 per cent., the lowest shown by any one of the institutions being 12.8 per cent. The 765 cases treated with his serum showed a mortality of but 4 per cent.

For Jez's antityphoid extract, obtained from the organs of animals inoculated with typhoid bacilli, is claimed [3] that it reduces the temperature, strengthens the pulse, and shortens the attack. It is given at first in doses of 15 c.c. once or twice an hour, and, after the first remission, at intervals of three hours. When the morning temperature falls to about 100° F., the extract is given thrice daily.

By grinding typhoid bacilli frozen by means of liquid air, Macfadyen and Rowland [4] succeeded in obtaining their intracellular toxins, which they injected in small repeated doses into animals, which then yielded a serum which proved to be both antitoxic and bactericidal, neutralizing the isolated intracellular toxins and destroying the bacilli.

That the toxins of the typhoid bacillus are not wholly intracellular is asserted by Rodet, Lagriffoul and Wahby,[5] who found that, while the bacilli secrete toxic products, these are largely adherent to the exterior of the cell-substance, and are of unstable character. Nevertheless, experimenters believe them to be the cause of the systemic disturbance.

[1] Deutsche medicinische Wochenschrift, 1904, No. 7.
[2] Presse Médicale, 1904, No. 86.
[3] Therapeutische Monatshefte XV., 1901, No. 9.
[4] Centralblatt für Bakteriologie, etc., XXXIV., p. 618.
[5] Archives de Med. Exper. et d'Anat. Pathologique, July, 1904.

The preventive inoculation of sterilized cultures of typhoid bacilli appears to have been very successful. Among the favorable reports the following may be cited: Wright[1] reports that of 11,295 men of the British Indian army under observation for nine months, 0.95 per cent. of those inoculated (2,835) and 2.5 per cent. of those not inoculated (8,460) acquired the disease. Of a smaller number of susceptible persons, Wright[2] reports that 1 in 77 of the inoculated (541) and 1 in 4 of the non-inoculated (114) were seized.

In the beleaguered garrison of Ladysmith, South Africa, there was much typhoid fever. Between November 2, 1899, and February 2, 1900, there were 1,489 cases among the 10,529 who were not inoculated, and only 35 among the 1,705 who had been inoculated, instead of 250, which would have been the probable number otherwise. The death-rates of the two groups were respectively 3.12 and 0.047. Later statistics published by Wright[3] deal with a much larger number of men of the Indian and South African armies. In India there were 744 cases of the disease with 199 deaths among 55,955 non-inoculated soldiers—an attack-rate of 1.33 and a death-rate of 0.36 per thousand; but among 4,883 who were inoculated, there were but 32 cases with 3 deaths—an attack-rate of 0.66 and a death-rate of 0.06 per thousand. In South Africa the attack-rates for the non-inoculated and inoculated soldiers were respectively 2.3 and 1 per thousand.

Crombie,[4] in a consideration of the effects of antityphoid inoculation in South Africa, lays particular emphasis on the influence of age. In persons under 30 the advantage of inoculation is marked, the incidence among the inoculated being about half that among the non-inoculated; but beyond that age the reverse is the fact, the incidence among the non-inoculated being about half that among those who had undergone one treatment. He suggests that as the period of greatest susceptibility (20 to 25 years) passes, inoculation tends rather to increase the probability of becoming infected. Wright[5] emphasizes the fact that in preventive inoculation there is danger if the subject's natural resistance is reduced, as is often the case, by a previous attack, and when an excessive dose is given or reinoculation is performed after too short an interval, and also when a full dose is given in actually infected surroundings.

Besredka[6] asserts that he has succeeded in producing a means of immunization which is free from the disadvantage of local and general reaction, and produces immunity which is much more lasting. An emulsion of the living organisms is mixed with immune serum that has been heated so as to destroy the complements but not the amboceptors, and is allowed to stand for a number of hours, during which time union occurs between the latter and the bacteria. The mixture is

[1] British Medical Journal, January 20, 1900.
[2] Ibidem, October 26, 1901.
[3] British Medical Journal, October 10, 1903.
[4] The Lancet, August 16, 1902.
[5] British Medical Journal, August 16, 1902.
[6] Annales de l'Institut Pasteur, XVI., No. 12.

then heated on a water-bath to 60° C., and the organisms are thereby killed. After thorough washing the organisms with the antibodies which have united with them are used as an injection. Besredka claims that immunity is produced within 24 hours; that it lasts at least five and a half months; and that neither local nor general symptoms follow the injection.

Wassermann,[1] believing that immunity is dependent upon the use of a culture which will fit the patient's receptors rather than upon the degree of virulence of the culture, recommends the employment of a number of races of the specific organism in the preparation of a true polyvalent agent. The mixed cultures are killed by heat and allowed to undergo autolysis, and then the liquid is evaporated *in vacuo* and the residue reduced to a powder, which may be kept unchanged. Such an immunizing agent may be prepared also for Asiatic cholera.

ASIATIC CHOLERA.

Preventive inoculation against Asiatic cholera actually antedates the antitoxic treatment of diphtheria, since it was in 1890 that Haffkine, inspired by Pasteur's discovery in 1880 that chickens could be rendered immune to chicken cholera by preventive inoculation, discovered that the same was true of human beings in respect to Asiatic cholera. First he experimented upon himself, and then made 70,000 injections of living cholera germs into 40,000 people in India within a period of two years. By inoculating only a part of any given population where cholera was raging, he was sure of a control by which he could judge of the value of his work. The rate of attack among those inoculated fell to about one-twentieth, and the mortality in about the same proportion.

Experimental work by Kolle led to the conclusion that sterilized cultures possess the same immunizing power, and on his recommendation that such be used in place of the living organisms, Murata[2] adopted this means of conferring immunity and employed it most extensively. Of every 10,000 persons so inoculated, 6 contracted the disease, against 13 of the same number not treated. This difference in the number of seizures is, however, hardly large enough to be regarded as having much probative force, but it is worthy of note that the mortality among the inoculated was considerably lower and the severity of the attack was less marked. Besredka prepares an anticholera injection in the same way that the antityphoid injection above described is produced, and claims for it the same advantages.

BUBONIC PLAGUE.

It is to Haffkine also that the prophylactic treatment for bubonic plague is due. He discovered that immunity could be attained by injecting sterilized cultures of the specific bacilli (treated at 70° C.

[1] Festschrift zur sechzigsten Geburtstage von R. Koch, 1903, p. 526.
[2] Centralblatt für Bakteriologie, etc., 1904, XXXV., No. 5.

for an hour or longer). The injection causes slight fever, with enlargement of the nearest lymphatic glands, but all evidence of reaction disappears in from 2 to 3 days. While the treatment confers some degree of immunity, the duration thereof is very uncertain: it may be two days or several months. Haffkine asserts that it lasts from 4 to 6 months and sometimes for as long as 2 years, but the weight of evidence tends to indicate that it is not safe to count upon a more lasting immunity than 3 months, and hence that reinoculation every 3 months is advisable. Calmette has called attention to the fact that inoculation of persons in whom the infection is already present in the incubative stage will hasten the appearance of the disease and conduce to a fatal result. Personal investigation, in India, of the results obtained led B. R. Slaughter[1] to conclude that the treatment acts within 24 hours and renders the subject immune for 3 months; that when applied during the stage of incubation, it frequently aborts the disease; that it has no effect on other diseases excepting eczema, which appears to derive benefit therefrom; and that the chances of recovery are greatly increased in case of attack in spite of the inoculation.

According to a report of the Plague Commissioners in India, of 4,296 persons inoculated once, only 45 contracted the disease, and of 3,387 inoculated twice, 2 were seized. Fifteen of the former and 1 of the latter died. At the same time, among the non-inoculated persons, no less than 657 per thousand died in a single week (the third week of September, 1899). At Kirkee (India) the plague broke out in a small camp; 671 persons were inoculated and 859 were left unprotected. Thirty-two cases occurred among the inoculated and 143 among the uninoculated. The mortality among the inoculated was 2.05, and among the uninoculated, 11.40, per cent. In another camp, 324 persons were inoculated and 300 left unprotected. Fourteen cases occurred among the uninoculated and none among those protected.

From further statistics which demonstrate the value of the treatment, the following may be quoted: In the Bombay Presidency, in one community, among 365 persons who were inoculated there were 13 cases with 3 deaths, while among 413 not inoculated, there were 48 cases with 36 deaths. In another community there were 7 deaths among 5,184 inoculated, and 177 among 8,146 not inoculated. At Lanowli, among 323 who were inoculated, there were 14 cases with 7 deaths, and among 377 not inoculated, 78 cases with 58 deaths.

Immunity appears to be prolonged by a second inoculation within ten days of the first, as is shown by the following figures: At Shawar, among 5,614 persons not inoculated, there were 957 cases with 756 deaths; among 5,712 who were inoculated but once, there were 69 cases with 31 deaths; but among 3,349 who were inoculated twice, there were only 9 cases with 5 deaths.

Prior to the discovery of the Haffkine prophylactic, Yersin's anti-pest serum, which is the only known remedy for the cure of the disease, was employed as an immunizing agent, but the duration of immunity

[1] Bulletin of the Johns Hopkins Hospital, November, 1903.

was found rarely to exceed two weeks, and hence the treatment must be repeated every fourteen days in order to insure protection. It is claimed by Calmette that the serum confers an immunity, certain and effective, almost immediately after the injection; that the injection is not painful and is never harmful; and that the serum, properly prepared, retains its power almost indefinitely. On the other hand, the disadvantages are the short duration of immunity, the great cost of production, the difficulty of obtaining a supply sufficient for the repeated treatment of entire populations, and the difficulty of inducing the natives to submit even once to the operation. It takes from seven months to a year to immunize a horse to the point that his serum acquires preventive and curative properties, and many of the horses die before the process of immunization is completed. According to Assistant Surgeon-General Greenleaf, protective inoculation by means of the Yersin serum is not practical for the following reasons: The enormous plant necessary for the production of the material; the large working force necessary for conducting the inoculations; the opposition of the people to the treatment; and the short duration of the benefit conferred.

Cairns,[1] who used the serum with some success in the treatment of cases at Glasgow, concludes that it is both antitoxic and bactericidal, and that it produces its best effects when the injection is made early and both subcutaneously and intravenously, the total initial dose ranging from 150 to 300 cc., according to the circumstances of the case.

Besredka's prophylactic is prepared in the same way and has the same advantages as those which he prepares for typhoid fever and cholera, but the organisms are first killed by heating to 60° C. for an hour on the water bath, before being mixed with the antiserum.

Both the Yersin serum and the Haffkine prophylactic are very unpopular with the natives of India. The Hindoos suspect that the materials are of animal origin, and the injection of such matters into the body constitutes an offence against their religion.

ANTISTREPTOCOCCUS SERUMS.

Antistreptococcus serums of various kinds have been employed in the treatment of **Erysipelas, Puerperal Sepsis, Malignant Endocarditis** and other streptococcic infections and **Scarlet Fever**, but thus far they have not given results that indicate that they are of much value. They have been prepared by inoculating with living cultures of streptococci and with the intracellular substance of killed cultures, and, on account of the asserted differences in the organisms according to the nature of the pathologic processes in which they are a factor, with cultures obtained from a number of subjects with different diseases, and also with cultures taken directly from a number of individuals with the same disease, as is the method followed by Moser in the preparation of his poly-

[1] Therapeutische Monatshefte, May, 1904.

valent serum for scarlet fever. They have been prepared also by inoculating with organisms rendered unusually virulent by being passed through a series of animals.

How these various serums produce such results as have been observed is a matter of some disagreement. It is believed by some that they are bactericidal, but this is denied by others, who believe that they act as stimuli to the phagocytic cells. However they may act, the hoped-for results have not been attained, and immunity to streptococcic invasion is evidently a very complex problem.

TUBERCULOSIS.

In the treatment of tuberculosis, Maragliano's serum, for which are claimed both antitoxic and bactericidal properties, and Marmorek's, which is antitoxic only, have failed thus far to yield other than disappointing results, although the principal advocates of each have asserted otherwise. No progress worthy of note has been made in the serum treatment of **Pneumonia**; indeed, it has scarcely entered the laboratory stage of experimentation.

CHAPTER XVII.

VACCINATION AND SMALLPOX.

PRIOR to the discovery of vaccination by Jenner, toward the close of the eighteenth century, smallpox was one of the principal scourges of the world. It killed, on an average, nearly half a million people in Europe alone, and about once in three years was more than ordinarily severe. In England, Germany, France, Sweden, and other countries of Europe, the yearly mortality from smallpox was about two thousand per million inhabitants. More than half the cases of blindness throughout Europe were attributed to the disease, and about a third of the population showed in their faces evidences of having had it.

It was well known that those who recovered enjoyed protection from recurrence of the disease, and consequently it had long been the practice to produce immunity by causing the disease intentionally by inoculation when it prevailed in a modified form, favorable to recovery. For more than a thousand years, the Chinese and other Eastern peoples had produced the disease by blowing dried smallpox matter in powdered form into the nostrils. The discovery that the inoculation of material from a smallpox pustule was more certain and quick in its results led to the widespread practice of inoculation. This was begun in England in 1721, and toward the end of the century was employed very extensively; and even after the discovery of the beneficent results of vaccination, was practised to a certain extent, until, in 1840, it was prohibited by law.

The first successful vaccination was performed by Benjamin Jesty, a Dorsetshire farmer, who inoculated his wife and two sons from the teats of cows afflicted with cowpox. The inoculation was successful in all three cases, although the wife had a badly inflamed arm. Fifteen years later, the two sons were inoculated with smallpox, but nothing resulted. It is said that Heim[1] had noted as early as 1763 that the accidental inoculation of cowpox was followed by smallpox immunity. The practice of vaccination is, however, due to the work of Jenner, who, on May 14, 1796, performed his first successful operation. After some very strong opposition, intelligent people began to adopt the practice, and the uneducated classes began to fall gradually into line. The practice was adopted in America, France, Germany, and, in fact, the entire civilized world, and everywhere proved to be of the greatest benefit. In 1802, the English Parliament awarded Jenner

[1] Nothnagel's Specielle Pathologie und Therapie, IV., H. 2.

4,000 pounds sterling, and later, a still larger grant was made. But the pioneer, Jesty, was not lost sight of, and in 1805 he was the honored guest of the Jennerian Society.

The practice was introduced into this country by Dr. Benjamin Waterhouse, Professor of Physick in Harvard University, who, on July 8, 1800, vaccinated his seven children, with six positive results. About the same time it was introduced into Philadelphia by John Redman Coxe, who vaccinated his eldest child and then exposed him to smallpox without result. In Boston, in August, 1802, 19 boys were vaccinated successfully at a temporary hospital on Noddle Island (now East Boston), and in November, these and one other, who had been vaccinated two years previously, were inoculated with smallpox, but in no case was the disease produced. Two unvaccinated boys were inoculated at the same time, and both developed the disease. In 1806, Thomas Jefferson, who was the first to introduce the practice in the South, wrote to Jenner: "You have erased from the calendar of human afflictions one of its greatest. Yours is the comfortable reflection that mankind can never forget that you have lived. Future nations will know by history alone that the loathsome smallpox has existed, and by you has been extirpated."

The beneficent results of the introduction of vaccination into this country are well shown by a comparison of the conditions obtaining in the early part of the eighteenth century and in the corresponding period of the nineteenth in Boston. In 1721, Boston, with a population of about 11,000, had 5,989 cases of smallpox with 850 deaths. In 1730, in a population of about 15,000, there were about 4,000 cases with 509 deaths; but between 1811 and 1830, in a very much larger population, there were but 14 cases of the disease.

In London, during the third quarter of the seventeenth century, the average annual mortality from smallpox per million was 4,000. A hundred years later, between 1770 and 1780, it was more than 5,000; in the first years of vaccination, it was more than 2,000; by the middle of the nineteenth century it fell to about 500, and in the last decade of the century, to less than 75. In the whole of England, during the peroid of optional vaccination, the mortality-rate fell from about 2,000 to 417, and after the practice was made compulsory in 1850, it fell to 53. In August, 1898, the "conscientiously believes" clause was enacted in deference to the anti-vaccinationists, and by December 31, 230,147 persons were exempted. The result of this modification of the law has recently been shown in extensive epidemics in London and elsewhere.

In Sweden, where very accurate records have been kept since 1774, the average mortality per million of population, between 1774 and 1801, was 2,045. During the years of optional vaccination, 1802–1816, it fell to 480. In 1817, when vaccination was made obligatory, the rate began to fall still lower, and up to 1893 the average mortality was 155. During the last nine years of this period, under more stringent regulations, it was never more than 5, and in one year it was as low as 0.2.

In Prussia, during the period of optional vaccination, the mortality rate fell from more than 2,000 to about 300. During the Franco-Prussian War, there were among the million well-vaccinated German troops but 459 deaths, while in the smaller, imperfectly vaccinated French army there were no less than 23,400. Between 1874, when vaccination was made obligatory, and 1896, there was but one death from smallpox in the whole German army. In 1899, the total deaths in 285 German cities and towns, with a population of nearly 16,000,000, amounted to only 4. In the same year, in France, where vaccination is not universal, there were 600 deaths in 116 communities with a population of 8,500,000.

In Austria, Hungary, and Belgium, where the practice is not required, the death-rates were, in 1886, respectively 81, 687, and 48 times that which obtained in Germany. In Spain, where, also, the practice is optional, the death-rate in six provinces, in 1889, was 12,050 per million against one of 4 per million in Germany.

In Denmark, where vaccination was made obligatory in 1816, not a single case was known up to 1826.

In Porto Rico, before the Spanish War, the annual mortality from smallpox was about 600; but since the wholesale vaccination by the United States authorities, the disease has virtually disappeared.

In all countries where vaccination has, at different periods, been optional and then required, a remarkable drop has occurred both in morbidity- and mortality-rates, and those countries in which, to-day, vaccination is not compulsory, suffer periodical visitations of the disease and lose thousands of lives. In 1889, for instance, the death-rate from smallpox in Spain was nearly as great as obtained a century before in the principal countries of Europe, while in the same year, in Germany, the disease was practically non-existent. In France, in the twenty-five years from 1870 to 1895, more than 20,000 people died from smallpox in Paris alone, the epidemics of 1871 and 1872 being exceptionally severe and fatal. No epidemic has occurred in Germany since 1871, when the disease was brought in by French prisoners, although a few scattered cases have appeared occasionally.

In spite of the remarkable testimony concerning the value of vaccination in making a rarity of what was once one of the principal scourges, there are in this country and in others where laws compelling vaccination have been enacted, numerous misguided individuals who band themselves together into anti-vaccination leagues and attempt to create a popular antagonism to the practice and to effect repeal of existing laws. In England, as has been noted, they have been partially successful in compelling the passage of a law which exempts parents who have "conscientious scruples" against having their children vaccinated. In progressive Japan, where the government has decided to compel vaccination before the age of ten months, and revaccination at the age of six and again at twelve, the anti-vaccinationist is unknown.

The following table shows the smallpox mortality of the several

countries named, in which vaccination is either not compulsory or imperfectly performed, as compared with that of Germany, which in each year is represented by 1:

	1893.	1894.	1895.	1896.	1897.	1898.	1899.
Switzerland	8	96	3	17	...	25	...
England	24	108	19	23	16	4	42
France	34	261	201	1,176	123	22	231
Austria	67	132	28	177	247	121	67
Belgium	158	145	25	57	21	86	174
Holland	...	640	81	147	7	5	...
Germany	1	1	1	1	1	1	1

It cannot be claimed that vaccination confers absolute immunity against smallpox, but it is true that those who have been vaccinated and then acquire the disease have it in a much milder form and are more likely to recover than those who have not been vaccinated. Investigation of 11,036 cases of smallpox in England showed that, for unvaccinated and vaccinated cases, the rates of mortality were respectively 36.6 and 5.2 per cent., and that for all cases in children under ten, the rates were respectively 36.2 and 2.7 per cent. Among those stricken during the epidemic at Warrington, England, in 1891–92, 21.8 per cent. of the cases in vaccinated persons were confluent, while among the unvaccinated cases, the percentage was 70.6. In the Sheffield epidemic of 1887–88, 1.55 per cent. of vaccinated and 9.7 of unvaccinated persons were attacked. Among the former, the death-rate was 0.7, and among the latter, 48 per thousand. Among children under ten, the rate of attack was 5 and 101 per thousand, respectively, for vaccinated and unvaccinated, and the death-rate was 0.09 and 44.

The protection conferred by vaccination is greatest during the year succeeding the operation, and appears to diminish gradually during the succeeding five or six years; but the modifying power does not diminish equally fast. The protective influence can be reëstablished by a repetition of the operation, and during epidemics, or when about to visit countries where vaccination is not practised and smallpox is endemic, revaccination is always advisable. If the operation is negative in its results, the individual is regarded as immune or partially protected; but in the case of a first vaccination, it is customary to repeat the operation until success is attained. In most civilized countries, vaccination is not postponed until an outbreak of smallpox occurs, but is attended to in the first few months of life.

Successful primary vaccination within three days after exposure to existing cases of smallpox will prevent the development of the disease, and as late as the fifth or sixth day will either prevent or modify an attack. This fact has been utilized in many cases where smallpox has broken out among unprotected people with a prospect of unlimited spread, and has been the means of ending epidemics with some suddenness. Thus, for example, at Gloucester, England, in 1895, after eight years of practical abandonment of compulsory vaccination, that

is to say, of neglect on the part of the authorities to enforce the law, an epidemic of smallpox occurred in what was practically an unvaccinated community. The cases increased at such a rate that great alarm was felt and extensive measures were taken for general vaccination. In the closing weeks of 1895, 31 cases occurred. In January, 28 more were reported. In February, the number increased suddenly to 146, and during March, to 644. Toward the last of that month, the authorities gave directions for enforcement of the law, and work was begun; but during the following month, no less than 744 cases occurred. During the last days of April, a committee undertook general vaccination of the city, and within a very few days, every house had been visited; by the end of June, the city had been converted from a practically unvaccinated city to the best vaccinated in the country. Nearly 36,000 persons were operated upon; the epidemic began at once to decline, and before August had disappeared. Nearly 450 persons, however, had died, and 1,600 others who survived, bore the usual lasting evidence of the disease in their faces.

As showing the influence of revaccination, the following figures from a study of the statistics of the Sheffield epidemic are presented:

Rates of attack per 1,000 persons.

Persons not vaccinated	94
Persons once vaccinated	19
Persons twice vaccinated	3

Death-rates per 1,000 persons.

Persons not vaccinated	51
Persons once vaccinated	1
Persons twice vaccinated	0.08

Similar facts are yielded by investigation of all epidemics where there is a large class of vaccinated and another of unvaccinated persons, and yet anti-vaccinationists still agitate and find sympathetic listeners to their arguments. One of their favorite charges is that vaccination not only has had nothing to do with the decline in the amount of smallpox, but, on the contrary, gives rise to other diseases. It is, indeed, true that syphilis has been conveyed from one to another through the practice of vaccination, but at the present time the danger is practically *nil*, since arm-to-arm vaccination has fallen into disuse; but while the arm-to-arm practice was continued, there were occasional instances of grave injury. Thus, some years since, it happened that a company of French infantry, prior to being sent to Algiers, was vaccinated by the arm-to-arm method, and very many of the men were thereby inoculated with syphilis.

Parents are prone to ascribe to vaccination every disturbance which a child may suffer, particularly if there be any cutaneous eruption. Sometimes a vesicular or pustular rash may occur and spread from the vaccinated arm to other parts of the body; sometimes, erysipelas and other infections occur at the point of vaccination; but these are no more likely to occur as a result of vaccination than of any other interference with the integrity of the skin. Persons of dirty habits, living

in unclean surroundings, are more likely than others to suffer from ulceration of the vesicle and from other local disturbances not due to the influence of the virus itself.

With regard to the assertion that the three weeks following vaccination are a period of unusual danger from the various zymotic diseases, the results of extensive study by Dr. Voight, Director of Vaccination at Hamburg, are of interest. According to his records, the reverse of this assertion is true, for the process appears to exert a restraining influence upon the development of practically all of the infectious diseases. According to Dr. J. M. Mackenzie,[1] scarlet fever, whooping cough, influenza, and syphilis are favorably influenced, tuberculosis and enteritis may be unfavorably influenced, and latent eczema and impetigo may be excited.

In revaccination, if the individual has become again wholly susceptible, the local manifestations occur earlier than in the primary vaccination, and the general symptoms are usually much more marked.

[1] British Medical Journal, August 15, 1903.

CHAPTER XVIII.

QUARANTINE.

Quarantine is a term of wide signification. Derived from the French *quarante*, forty, its original meaning had reference to the number of days' detention to which vessels and their personnel, arriving from places infected or suspected of being infected with the plague, were subjected in places set apart for the purpose, to insure against the introduction of the disease into the country or port of arrival.

The usual definitions of the term which, in a composite form, may be given as, "The enforced detention of vessels, their personnel, and cargoes, arriving from infected ports, or having, or being supposed to have, cases of certain infectious diseases on board, and interdiction for a fixed period of time of all communication therewith," are wholly inadequate under present conditions. Far more accurate and comprehensive is that given by Dr. Walter Wyman, U. S. P. H. and M.-H. S.: "The adoption of restrictive measures to prevent the introduction of diseases from one country or locality into another," for the original meaning is now quite lost. To-day, we speak of port quarantine, land, interstate, railroad, municipal, house, and room quarantine. Restrictive measures are not adopted solely against human diseases, but also against those of the lower animals (cattle quarantine), and even of certain fruits and other important crops.

The necessity of restrictive measures in certain cases has long been recognized; in fact, in the case of leprosy, from earliest times. The first enactment providing for the detention and isolation of travellers from infected places dates back to the fifteenth year of the Emperor Justinian (A. D. 542), but quarantine in the modern sense had its origin in the fourteenth century in Italy, where, on account of the ravages of the plague, local authorities at different times adopted preventive measures. Thus, Florence and Venice, in 1348; Lombardy, 1374; Milan, 1399.

The first maritime quarantine was instituted, in 1403, at Venice. A lazaret, the house of St. Lazarus, was founded on a small island, and all persons from the Levant were there detained for forty days before admission to the city. The restrictive measures enforced at Mediterranean ports and elsewhere, were for many years, and at some places now are, unreasonable, harsh, useless, and a great injury to trade. Most of the leading countries have, for a long time, been strongly opposed to the oppressive, arbitrary, and irrational quarantine measures, and have now adopted rules and regulations, which, while effective as far as can be hoped for or expected, impose the least

possible restrictions upon personal liberty and trade. The danger is estimated according to the condition of health of the port of departure, and this, with the sanitary history of the vessel, up to the time of arrival, determines what measures, if any, are to be taken.

The periods of detention are fixed with reference to the probable incubative period of the disease in question, and questions of necessity of disinfection, and of methods to be followed in carrying out the same, are determined by the circumstances of each individual case. Quarantines administered with reason do invaluable work in sifting out infection and protecting the public health from exotic diseases, which, in the absence of precautionary measures, might easily gain access. At the same time, they act in restraint of trade to the slightest possible extent, since uninfected vessels are not unnecessarily detained.

Unfortunately, not all quarantines are administered with reason, and it often happens that great injustice and unnecessary expense are caused by absurdly tenacious adherence to exploded theories and routine practice. As an example, may be cited the case of the *Helene*, a German vessel, which, arriving in an English port in August, 1893, with two cases of cholera, was disinfected and given free pratique; nine months later, she was refused pratique at a South American port, because in England she had not been held for a definite period at quarantine. As an example of quarantine absurdity of a minor character, but indicative of what might be imposed in case opportunity presented itself, may be cited an experience with the municipal authorities at a Southern port, who required thorough disinfection of a barrel of carbolic acid before it was allowed to be landed.

Far more and almost incredibly absurd is the following instance: On November 3, 1893, the steamship *Cabo Machichaco*, laden in part with dynamite, blew up at her dock at Santander, Spain, after having been on fire for some hours. The burning cargo was thrown about in all directions and started a general conflagration. It happened that the entire fire department was, at the time of the explosion, engaged in attempting to overcome the fire raging in the ship's hold, and in the explosion was completely wrecked. Word was sent to Bilbao, and aid was urgently requested. Two steamships were sent with fire engines, firemen, surgeons, nurses, laborers, and others, and arrived in six hours. The provisional governor refused to permit the vessels to dock and discharge the much-needed apparatus and other aid, because quarantine had not been observed, and he insisted that they should comply with the regulations, which would involve several days' detention outside the harbor. It was several hours before a way was found to overcome the strict interpretation of the rules.

The first action taken by any official organization in this country looking to the establishment of a uniform system of quarantine regulations was at a conference of boards of health at Philadelphia in 1857, called on account of the excitement caused by the breaking out of yellow fever at Bay Ridge in the previous year; but in spite of this and other attempts, the various quarantines of the country were administered

with no uniformity until after the passage of the Act of February 15, 1893, entitled "An Act granting additional quarantine powers and imposing additional duties upon the Marine Hospital Service." This act established a national system of quarantine, but in no way limited State and municipal authorities in their right to prescribe and enforce additional measures; and, indeed, it is beyond the power of Congress to interfere with local authorities so long as the minimum requirements of the national law are complied with.

Quarantine Law of 1893.

Section 1 makes it unlawful for a vessel from a foreign port to enter any port of the United States, except in accordance with the provisions of the act and with such rules and regulations of State or municipal health authorities made in pursuance of or consistent therewith, under penalty of not exceeding $5,000.

Section 2 provides that a vessel at a foreign port, clearing for any port in the United States, shall obtain from the consular or medical officer of the United States at that place a bill of health in duplicate, in the form prescribed by the Secretary of the Treasury, setting forth its sanitary history and condition, and that it has complied with the rules and regulations prescribed for securing the best sanitary condition of the vessel and its cargo, passengers, and crew. Penalty for clearing and sailing without such bill of health and entering any port of the United States, not exceeding $5,000. By an amendment approved August 18, 1894, it is provided that the provisions of this section shall not apply to vessels plying between foreign ports on or near the frontiers of the United States and ports of the United States adjacent thereto. But the Secretary of the Treasury is authorized, when, in his discretion, it is expedient for the preservation of the public health, to establish regulations governing such vessels.

Section 3 directs the Supervising Surgeon-General of the U. S. Public Health and Marine-Hospital Service to coöperate with and aid State and municipal boards of health in the execution and enforcement of the rules and regulations of such boards and of those made by the Secretary of the Treasury to prevent the introduction of contagious or infectious diseases into the United States and into one State, Territory, or the District of Columbia from another.

It provides that all rules and regulations made by the Secretary of the Treasury shall operate uniformly and in no manner discriminate against port or place. Where no State or municipal quarantine regulations exist, and in the opinion of the Secretary of the Treasury are necessary to prevent the introduction of such diseases, and where existing regulations are in his opinion insufficient, he shall make such additional rules and regulations as he may deem necessary, and they shall be enforced by the respective sanitary authorities; failing which, the President shall execute and enforce the same and adopt such measures as in his judgment are necessary, and may detail or appoint

officers for that purpose. The Secretary of the Treasury shall make such rules and regulations as are necessary to be observed by vessels at the port of departure and on the voyage, to secure the best sanitary condition of themselves, their cargoes, passengers, and crews.

Section 4 makes it incumbent on the Supervising Surgeon-General to perform all the duties in respect to quarantine and quarantine regulations, and to obtain information through consular officers of the sanitary condition of foreign ports and places from which contagious and infectious diseases are or may be imported into the United States. The Secretary of the Treasury is required to obtain through all available sources, including State and municipal sanitary authorities throughout the United States, weekly reports of the sanitary condition of ports and places within the United States, to transmit to collectors of customs and to State and municipal health officers and other sanitarians weekly abstracts of the consular sanitary reports and other pertinent information received by him, to procure, through all available sources, public or private, information relating to climatic and other conditions affecting the public health, and to make an annual report to Congress, with such recommendations as he may deem important to the public interests.

Section 5 provides for the issuance from time to time to the United States consular and medical officers at the various foreign ports, of the rules and regulations made by the Secretary of the Treasury to be used and complied with by vessels in foreign ports for securing the best sanitary conditions before departure for the United States, and in course of the voyage, and of all other rules and regulations as shall be observed in inspection on arrival at any quarantine station and for disinfection and isolation, and treatment of cargo and persons on board, so as to prevent the introduction of cholera, yellow fever, and other contagious or infectious diseases. No vessel shall enter a port or discharge its cargo or land its passengers except upon a certificate of the health officer at such quarantine station that the rules and regulations have in all respects been observed and complied with both by him and by the master in respect to the vessel and its cargo, passengers, and crew. The master is required to deliver to the collector with the other papers of the vessel, the bills of health obtained at the port of departure and the certificate above mentioned.

Section 6 provides that on the arrival of an infected vessel at any port not provided with proper facilities for treatment, the vessel shall be remanded at its own expense to the nearest national or other quarantine station where accommodations and appliances are provided for the necessary disinfection and treatment of vessel, passengers, and cargo. After treatment of such vessel and after certification by the United States quarantine officer that vessel, cargo, and passengers are free from infectious disease or danger of carrying the same, the vessel shall be admitted to entry at any port of the United States named in the certificate. But at ports where sufficient quarantine provision has

been made by State or local authorities, the Secretary of the Treasury may direct the undergoing of quarantine at said station.

Section 7 provides that whenever the President is satisfied that by reason of the existence of cholera or other infectious diseases in a foreign country there is serious danger of the introduction of the same into the United States, and that notwithstanding the quarantine defence this danger is so increased by the introduction of persons or property from such country that a suspension of the right to introduce the same is demanded in the interest of the public health, he shall have power to prohibit, in whole or in part, the introduction of persons and property from such countries or places as he may designate, and for such period of time as he may deem necessary.

Sections 8 and 9 are of no sanitary interest.

In accordance with the provisions of this act, certain rules and regulations to be observed at foreign ports and at sea and at ports and on the frontiers of the United States have been adopted and amended and added to as occasion has made it necessary or advisable. These rules are subject to very material modifications or additions, based on a wider knowledge of the causes of disease, modes of infection, etc., and thus what may be law today may be superseded tomorrow. Thus the very strongest regulations with regard to yellow fever, which were made before the method of its dissemination was known, and with the idea that infection could be conveyed by fomites, merchandise, baggage, etc., will undoubtedly be changed completely in consequence of the discovery, by Reed and his associates, that infection cannot thus be conveyed. It is only reasonable, in view of their work, that quarantine restrictions upon passengers and cargoes from non-infected ports should be very greatly modified, and that, in each instance of vessels from infected ports, the incubative period of the disease, the possibility of the presence of infected mosquitoes on board, and the length of time a mosquito requires for the acquirement of dangerous properties, should be kept in mind. Reed believes that a vessel at an infected port can be loaded in midstream by lighters, and can then become infected only by persons who have been exposed on shore, since the probability of mosquitoes reaching the ship by flying or by lighters is very slight. If, then, a vessel thus loaded arrives at its destination free from disease, the non-immunes aboard should be quarantined not longer than five days, and the time consumed by the voyage should be included in this period. The cargo may be allowed to be discharged without treatment or delay. But if the disease should occur while between ports, the sick should be removed, the sleeping quarters disinfected with sulphur dioxide in order to destroy all mosquitoes, and then the vessel should be allowed to dock. Under some circumstances, it may be necessary to fumigate the hold, for mosquitoes may be there in an active condition; although, unless they have access to moisture, they will not live longer than five or six days. Rosenau has kept them alive in trunks for ten days and longer, but moisture was provided.

If mosquitoes are found on board a vessel from an infected port, the

non-immunes should be detained, unless more than twenty days have already elapsed since clearing. This period will be sufficient to demonstrate the presence of infection in the mosquitoes, by the occurrence of cases during the voyage. If more than twenty days have elapsed, there can be no danger, and neither passengers nor cargo should be detained.

Since the publication of Reed's results and views, many cases have been cited in the medical press in opposition to the view that the disease cannot be spread by baggage, fomites, and cargoes, but in no instance which has thus far fallen under the author's observation can the mosquito be ignored. Indeed, in many of the cases, the disease has broken out, after an uneventful voyage and the formalities of quarantine, in places where the specific yellow fever mosquito is known to be indigenous. In some cases, mention is made of the fact that, in spite of the very numerous mosquitoes present where a case of the disease has been brought, no extension of the fever has been produced; but it is not stated that the mosquitoes were *Stegomyia fasciata*, which is a vital point in the argument.

In view of the probable extensive changes in the rules, it is deemed best not to reproduce here existing rules *in extenso*, but advise one to apply, as occasion arises, to the Treasury Department for a printed copy thereof.

As they stand at present, the regulations prescribe forms for bills of health, methods of inspection of passengers, crew, baggage, cargo, food and water supplies, and of the vessel itself; requirements as to cleanliness of vessels, and as to ventilation; methods of disposal of bedding; location and arrangement of the "sick bay"; what may not be taken on board at ports infected with certain diseases; what must be disinfected, and how; what persons may not be shipped, and periods of detention according to the nature of the disease to which they have been exposed; and general and particular rules to apply in certain cases. The regulations prescribe, also, requirements as to cleanliness and ventilation at sea; isolation of the sick; disinfection and disposal of the dead; and give in detail the methods to be followed in disinfection of all parts of a ship, of various kinds of cargoes, and of personal effects.

The regulations to be observed at ports and on the frontiers of the United States provide for the establishment of quarantine stations at or convenient to the principal ports of the country, and prescribe methods of inspection according to the circumstances of each case, as, for instance, for vessels from healthy or infected ports, and for vessels suspected of being infected with plague or yellow fever. Quarantinable diseases are named as follows: cholera and cholerine, yellow fever, smallpox, typhus, leprosy, and plague; and rules are laid down for the government of vessels on which any of these diseases have occurred during the voyage, and for the treatment and detention of passengers, crew, baggage, and cargo.

Following the passage of the quarantine law of 1893 and the promulgation of the regulations made in accordance therewith, at

many ports the quarantine service was surrendered voluntarily to the national government, and at others it was taken over by the same authority, because of non-compliance with the regulations. At others, the regulations have been adopted and efficiently enforced by the local authorities, but these and all others are inspected regularly by the Public Health and Marine-Hospital Service, to insure efficiency of administration and correction of faults in methods and defects in appliances.

In 1900, there were in the United States no less than 120 quarantine and inspection stations, of which number, 81 were on the Atlantic coast, 17 on the Pacific coast, and 22 on the Gulf of Mexico. They vary, naturally, very widely in importance and equipment, the most important one being that of New York, the chief gate of entrance of immigrants and of foreign commerce, and the least important being several with practically no arrivals of vessels from foreign ports. Only a small proportion are equipped with extensive disinfecting appliances, and but 8 are provided with quarters for the detention of persons held for observation.

Interstate Quarantine.

To prevent the introduction of contagious diseases from one State to another, Congress, on March 27, 1890, passed an Act providing that whenever the President is satisfied that cholera, yellow fever, smallpox, or plague exists in any part of the United States, and that there is danger of the spread thereof into other States, Territories, or the District of Columbia, he is authorized to cause the Secretary of the Treasury to promulgate such preventive rules and regulations as he may deem necessary, and to employ such inspectors and other persons as may be necessary to enforce them.

These rules and regulations shall be prepared by the Supervising Surgeon-General of the Public Health and Marine-Hospital Service, under the direction of the Secretary of the Treasury, and any violation thereof entails a fine of not exceeding $500, or imprisonment for not more than two years, or both, in the discretion of the Court. In the case of any officer or other person employed to prevent the spread of said diseases, wilful violation of any of the quarantine laws of the United States or of any of the rules and regulations made and promulgated as above, or of any lawful order of his superior officer or officers, the penalty is a fine not exceeding $300 or imprisonment for not exceeding one year, or both, in the discretion of the Court. Any common carrier or servant thereof who shall wilfully violate any of the same, shall be liable to a fine of not exceeding $500, or imprisonment for not exceeding two years, or both, in the discretion of the Court.

State Quarantine.

The national quarantine law and the rules and regulations made thereunder are, as has been said, intended only as minimum require-

ments, to which State or municipal authority may make such additions as may be deemed necessary for the preservation of the health of the people within its jurisdiction. Such additional requirements may be established for specific periods or without limit of time, and to meet general conditions or a special class of cases. As an example of special regulations made for a limited period, the following, adopted by the State Board of Health of Louisiana, with reference to vessels engaged in the tropical fruit trade during the season of 1899, may be cited.

"All vessels engaged in the tropical fruit trade between Central American, South American, and West Indian ports and New Orleans will be allowed to pass the Mississippi River Quarantine Station without detention longer than is necessary for a thorough inspection by day by the quarantine officers, so long as a properly accredited medical agent of this board certifies that such ports and places are free from contagious or infectious disease, and provided said vessels shall strictly conform to the following conditions:

"1. They shall not be allowed to bring to this port bedding or household effects of any kind.

"2. After leaving New Orleans, said vessels may take on board passengers during any part of their trip, and bring passengers to this port as herein provided.

"Cabin passengers only will be allowed at the discretion of the medical officer. This officer must satisfy himself that the applicant has not been in any infected locality in the past thirty days, and that none of his effects have been exposed to infection, and further such effects shall have been fumigated or disinfected before going on board.

"Passengers may be taken on board from one healthy port to another, each of said ports having a medical officer representing this board; under the same restrictions said passengers may be brought to New Orleans. Personal effects of passengers are restricted to personal wearing apparel, and should as much as possible consist only of clean, recently laundered clothing, and such effects, together with passengers' trunks, bags, valises or baskets, must be fumigated before being brought on board.

"The medical officer will refuse to permit the bringing of any unusual or unnecessary amount of baggage, it being the purpose of the board of health to facilitate the affairs of commerce by permitting passenger communication whereby business may be transacted in a safe manner, holding highest the health of the community; and it is insisted that material capable of carrying any possible infection should be limited to the least possible amount. Woollen bags or carpet sacks will be prohibited. Trunks should be of metal, wood, or paper; valises of leather or paper.

"The medical officer will make a personal inspection of all passengers and of every member of the crew just prior to the departure of the vessel, and give a certificate to the master of the vessel of the condition of such persons examined, marking opposite the name of each

person on the list furnished him by the officers of the vessel of every person on board such observations as may seem to him to be advisable concerning the condition of said person's present or previous state of health.

"Medical officers will invariably assist masters of vessels in treatment of members of crew or passengers taken sick on board vessels and should make notes of such treatment in writing to be sent to the quarantine officer at home ports.

"3. Vessels shall not touch at any infected port or have any communication with any vessel during their voyage except in case of distress.

"4. They shall not touch at such ports or stations as are not mentioned in their schedule, which latter shall be communicated to the board of health.

"5. They shall be required to make a full disclosure when arriving at quarantine station of all ports and places they have visited on their voyage.

"6. They may take on board a crew of laborers after inspection by the medical officer and disinfection of clothing of such crew for such healthy point where they permanently reside and remain, the crew being as nearly as possible composed of the same men. The captain or other officer may go ashore only for the purpose of entering or clearing vessels. Any further communication with shore or natives will be considered a violation of regulations, and vessels in default will be treated accordingly.

"7. These vessels shall be cleansed, and, when necessary, disinfected in the city of New Orleans after discharge of cargo."

Sanitary Cordon.

What is known as a sanitary cordon ("cordon sanitaire") consists of an extended line of guards thrown about a district to prevent access thereto or egress therefrom of any person or thing which may act as the carrier of infection. The object is, in other words, to protect the district from infection from the surrounding country or to protect the latter from infection from the district. Sometimes a double line is established, the territory intervening being, perhaps, only suspected of being infected. Cordons are not uncommonly established in the South against yellow fever, but are practically unknown in the North. In California, in 1900, a cordon was maintained, for a short time only, against a district in which cases of bubonic plague were believed to be concealed.

Municipal Quarantine.

Municipal quarantine comprehends measures for isolating those sick with certain of the infectious diseases, such as scarlet fever, diphtheria, and smallpox, keeping others under observation, and disinfecting rooms and houses and objects contained therein which may be capable of harboring infection. It is beyond dispute that public safety requires that certain sick should be shut off from free communication with the outside world. This isolation is most complete and entails less hardship

when it can be carried out at a special hospital for contagious diseases, but generally it is enforced, if at all, at the patient's home. Room and house quarantines are commonly difficult or impossible of enforcement, especially in tenement districts among the very poor, for it is among this class that danger of infection is least understood and mutual help and neighborly visiting most extensively practised, and thus the foci of infection may become increased indefinitely. In hospitals, on the other hand, where indiscriminate egress and ingress are under control and facilities for the disinfection of discharges are at hand, the danger of spread is reduced to a minimum.

Especially difficult and productive of hardship is the isolation not only of the patient, but also of the other members of his family. This is commonly practised in the case of smallpox, but is unnecessary if the other members have undergone recent successful vaccination, and their clothing and other effects are disinfected and they are then separated from all possible contact and communication with the patient. But even then, they should be kept under surveillance for a time equal to the period of incubation. In times of epidemics of yellow fever in the South, house quarantine of entire families has proved to be the cause of much hardship and anything but an unqualified success. It causes great popular dissatisfaction, leads to concealment of cases, and tends, therefore, to spread rather than restrict the disease. Treatment of the sick in isolation hospitals and removal of those who have been exposed to infection to camps of detention for five full days have been found to give far better results.

In some outbreaks of infectious diseases, it is necessary or advisable to conduct a house-to-house inspection for the discovery and isolation of unreported cases. When such a course is undertaken, the visits should be repeated at intervals equal to the period of incubation.

The making of regulations for municipal quarantine and inspection is subject to no general rule, each local authority being a law unto itself. In some cities, the rules governing notification, isolation, and disinfection are exceedingly thorough and strictly enforced; in others, they are inadequate in varying degrees and enforced with laxity.

Camps of Detention.—Camps of detention are places set apart for the reception and observation of persons who have been exposed or who are under suspicion of having been exposed to the contagion of smallpox or other quarantinable disease. They should be under strict surveillance and governed by inflexible rules. Every person should be examined before admission, and such effects as he may be permitted to bring in should be disinfected thoroughly, for above all things, it is necessary to guard against the introduction of infection. The entire personnel should be mustered in quarters and examined at least twice daily, and such as are beginning to show symptoms must be promptly isolated. Indiscriminate ingress and egress must be strictly prevented. At the expiration of the proper period, in each case the clothing and other personal effects should be thoroughly disinfected before discharge.

CHAPTER XIX.

DISPOSAL OF THE DEAD.

THE public health requires that the bodies of the dead shall be disposed of in such a way as not to be a menace to the living, and as soon as possible, with due consideration of the feelings of those bereaved. In the case of those dead of infectious diseases, disposal should not be delayed by sentimental considerations, but should be accomplished with as little delay as possible, on account of the risk to which the living may be subjected by the retention of the body in the home.

Concerning methods of disposal, consideration may be limited to the two in use by most civilized peoples and by most others as well; namely, earth-burial and cremation.

Earth-burial.—Interment of the dead has ever been the principal mode of disposal among Christians, Jews, and Mussulmans. Within comparatively recent years, the results of overcrowding of ancient churchyards and cemeteries, and the necessity of dedicating great areas of valuable land to be held in perpetuity for the accommodation of the dead, have brought about an economic sentiment against the practice, and to it has been added a feeling of danger to the public health from the decomposing tissues, particularly of those who have died of infectious diseases.

Buried in soil of suitable character, a body gives off for a number of months—six to nine may be regarded as reasonable limits—foul gases of decomposition which are not evolved in the later stages. The rate of decomposition is influenced not alone by the nature of the soil, its pore volume, and its degree of moisture, but also by the character of the coffin, the depth of interment, and the processes to which the body has been subjected before burial. After some years, the period varying within very wide limits according to circumstances,[1] decomposition is complete and but little remains besides bones, more or less crumbly in character.

It is charged against earth-burial, that the places used for the purpose are offensive; that the air becomes poisoned; that the soil becomes laden with disease germs of all descriptions, which are preserved indefinitely, and that water supplies are converted to dilute poisons of great potency; that is to say, cemeteries predispose to and act as direct causes of disease. As proof, numerous cases which will not bear close scrutiny are cited, but the whole mass of what is

[1] See case cited on page 293.

regarded as evidence of the connection of cemeteries with the outbreak of disease has but little real weight and is unconvincing. It has been said, for example, that typhus and other fevers were prevalent in the immediate neighborhood of old, overcrowded churchyards in London when it was customary to keep disturbing the soil for new interments, regardless of the number and condition of those already buried. Even though the supposed connection were anything more than mere coincidence, it may be said that nothing of the sort has been noticed within recent years, and never anywhere except in densely populated neighborhoods, in which densely crowded cemeteries happen to be located.

Cases of cholera, yellow fever, scarlet fever, and other diseases have been attributed to the opening of old graves. In one case, often quoted in all seriousness, a number of persons were seized with scarlet fever supposedly from digging up the surface of a burial ground where, no less than thirty years before, a number of victims of that disease had been buried. Sir Henry Thompson has said: "The poisons of scarlet fever, enteric fever, smallpox, diphtheria, malignant cholera, are undoubtedly transmissible through earth from the buried body by more than one mode. And thus by the act of interment we literally sow broadcast throughout the land innumerable seeds of pestilence; germs which long retain their vitality, etc., many of them destined at some future time to fructify in premature death or ruined health to thousands."

Such broad statements are easy to make, but exceedingly difficult or, indeed, impossible to substantiate. If true, it would appear that the earth, instead of being the great natural resolvent and disinfectant of all forms of dead organic matter deposited below the surface, is a mine of septic matter, in spite of which, the world at large continues to increase in health and the average length of life to extend little by little with every decade.

It is said also that the spores of all known species of pathogenic bacteria are very resistant and retain their virulence indefinitely. But even if this were true, and it is not true, it is not shown that the spore-bearers in the body form spores after death occurs. As a matter of fact, the basis of the bacterial scare concerning the dangers of earth-burial rests on no more solid foundation than the instance, quoted in the chapter on Soils, of anthrax spores supposed to have been brought to the surface by earthworms that had acquired them from a cow buried two meters below, which instance has no value as evidence for reasons already explained.

Coming to a consideration of the actual dangers arising from earth-burial and from the proximity of cemeteries, it must be admitted at the outset that merely stinking gases are incapable of transmitting disease, and are, moreover, absorbed and deodorized by the soil itself. The same class of foul odors are borne without injury by those engaged in the numerous offensive trades. There is no ground for supposing that the emanations from graveyard soil are

dangerous to health, for if they were, their effects should be most marked among grave-diggers, a class, who, like the workmen in sewers, are obstinately healthy in spite of all *a priori* reasoning to the contrary.

Whether the soil becomes seriously polluted, is a question which bears on the possible contamination of the ground-water. This possibility may exist, but it is as nothing in comparison with the pollution of the soil and its contained water by leaching cesspools, into which man casts yearly several times his weight of liquid and solid excreta from his own body, and there is recorded no single well-authenticated case of outbreak of disease due to water contaminated by the drainage of a graveyard.

On general principles, the drainage of a cemetery should not be allowed to run into streams used as water supplies, and wells should not be located in close proximity to the boundaries of land used for interments.

While burial too near the surface should be avoided on account of the possibility that the body may be exhumed by dogs and other animals, it is to be borne in mind that the nearer the body is to the surface, the more rapid will decomposition occur. In order to shorten as much as possible the time required for complete resolution, the coffin, which should not be of too permanent material, should be placed in immediate contact with the earth, and not in a bricked enclosure or vault. The use of wicker coffins is urged, since they offer less obstacles to the natural processes of resolution than any other. Metallic coffins which retain the products of decomposition indefinitely should be prohibited. The top of the grave should be a mound of earth capable of supporting a fairly luxuriant growth of vegetation, which assists in draining the soil and makes use of the products of decay.

Sites for Cemeteries.—In the selection of a site for a cemetery, particular attention should be given to the nature of the soil. This should be dry and permeable to air; the ground-water level should normally be well below the bottom of the deepest grave; the surface should be of rich loam, which acts as a powerful deodorant and provides for an abundant growth of vegetation. Clay soils are objectionable on account of dampness and impermeability, which prevent rapid decomposition of the bodies. Rocky soils are objectionable on account of their drainage and the obstacles to the digging of graves.

Much has been written concerning the danger of pollution of water supplies by the drainage of cemeteries, and this danger should be kept in mind, but it is unlikely that, with proper locations well away from habitations, serious pollution will occur. Where land is abundant and cheap, the immediate neighborhood of cemeteries for purposes of residence is generally avoided, but it is always well to pay attention to the proper drainage of lands devoted to burial purposes, and to consider the possibility of the fouling of any wells already present or likely to be sunk in the surrounding soil.

Cremation.—Disposal of the dead by burning was practised in very

early times as a mark of respect by some, or of dishonor by others, or from motives of expediency after great slaughter in warfare; but the practice of incineration, based on economic and sanitary considerations, is of quite recent origin among Christian peoples. The arguments urged in its favor from an economic standpoint are indisputable, for not only can the dead be thus disposed of much more cheaply, but the necessity of devoting large tracts of valuable land for purposes of burial is done away with.

From a sanitary standpoint, the arguments are not so strong and, in fact, are easy of refutation. It is urged that earth-burial is a menace to public health, and a number of supposedly convincing instances are cited as proof of this statement; but these cannot withstand the test of careful examination and weighing of evidence, and it must be admitted, even by the strongest advocates of cremation, that there is no definite statistical evidence that the general death-rate or any special death-rate has ever been influenced by earth-burial.

It is urged also that earth-burial is repulsive in idea and horrible in practice, and while, in the minds of many, this statement is true, it is to be said, on the other hand, that in the minds of far more, the argument applies with greater force to the practice of incineration. From the time of the early Christians, who practised interment by stealth, earth-burial has ever been the one method of disposal, and the sentiment in its favor, fostered through nineteen centuries of practice, is a powerful obstacle to the general adoption of cremation, and can only slowly be overcome. A strong feeling that cremation is opposed to Christian doctrine concerning the resurrection of the body can only be overturned by the influence of the clergy, many of whom, including Protestants and Roman Catholics of eminence, have already done much in advocacy of the practice as a rational, economic, and sanitary means of disposal.

Aside from religious feeling, the strongest argument urged against cremation is the destruction thereby of evidence of poisoning in cases in which, after disposal of the body, suspicion of foul play may arise; but when one considers the very great infrequency of exhumations on this ground, and the still greater infrequency of positive results therefrom, this objection can hardly be regarded as entitled to much weight. In the case of the metallic poisons, the evidence would still be present in most cases in the ashes; in the case of the organic compounds, it must be borne in mind that, under most favorable conditions, beginning the analysis before the onset of putrefaction, their detection in the small amounts commonly employed is by no means easy, and afterward is extremely difficult and more often impossible.

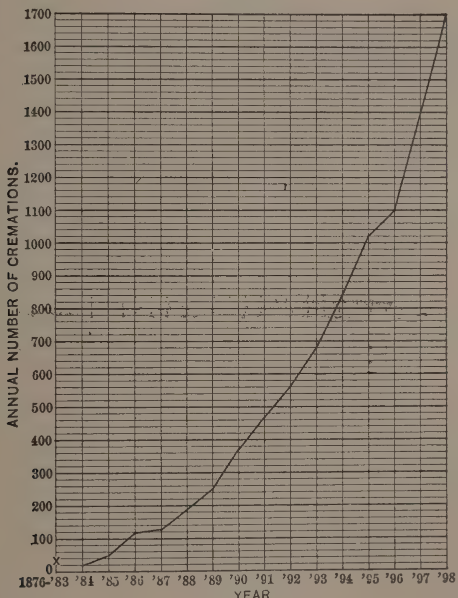
Furthermore, it must be borne in mind that, unless suspicion arises before or immediately after death, chemical analysis is commonly vitiated by the universal practice of embalming the body with strong solutions containing the very substances sought. In every case of doubt as to the cause of death, the body should be subjected at once to proper examination. In some States, legal provision has been made, forbid-

ding embalming in case of death by violence, until the body has been "viewed" by the proper authority, and providing for proper certification before incineration.

History of Modern Cremation.—According to Japanese authorities, cremation, as at present practised among civilized nations, had its origin in their country many years ago. Until 1871, however, no special crematories were installed, the body in its coffin being placed on stones surrounded by wood or other inflammable material. In that year, crematories were erected; and since then, the practice of incineration has increased to such an extent that, in 1897, in Tokio, of 34,000 persons who died, 15,000, or 44 per cent., were cremated. In 1898, the percentage was about the same.

In this country, the first movement in favor of cremation occurred in New York, in 1873, but the first crematory was not erected until

FIG. 118.



Curve showing number of cremations in the United States. (After ABBOTT.)

1876. This was built at Washington, Pa., by Dr. J. T. LeMoyne, for the disposal of his own body, and was the only one in the country until 1884, when another was established at Lancaster, Pa. During this interval of eight years, the use of his crematory was allowed by Dr. LeMoyne for others, and 25 incinerations were performed. Between 1884 and 1900, the number of crematories increased to 26, which growth indicates a steady increase in public sentiment in favor of the process. The number of cremations performed in the United States from 1884 to 1899 is shown in Figure 113 from the monograph

TABLE OF CREMATIONS IN THE UNITED STATES, 1876 TO 1899.

Crematories.	Date established.	1876 to 1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	Total.
New York City (U. S. Cremation Co.)	1885	...	...	9	77	67	83	106	160	187	186	232	243	296	330	331	466	2773
Buffalo, N. Y.	1885	...	...	1	8	17	16	23	30	38	27	30	31	41	28	44	40	374
Troy, N. Y.	1890	...	...	...	...	...	...	...	4	10	14	15	12	10	18	14	13	110
Swinburne Island, N. Y.	1889	...	...	...	...	...	...	...	2	...	60	28	8	1	1	3	3	106
Waterville, N. Y.	1893	...	...	...	...	...	...	...	...	...	...	1	1	6	5	4	4	21
St. Louis, Mo.	1888	...	...	...	...	...	21	20	42	60	64	72	87	96	86	118	109	778
Philadelphia, Pa.	1888	...	...	...	...	...	14	28	31	51	62	68	74	88	85	78	114	693
San Francisco, Cal. (Odd Fellows')	1895	...	...	...	...	...	...	...	...	...	...	...	...	66	101	214	260	641
Boston, Mass.	1893	...	...	...	...	...	...	...	...	...	...	1	87	88	135	160	167	638
Cincinnati, O.	1887	...	...	...	...	11	21	34	45	43	34	42	38	66	46	71	59	510
San Francisco, Cal. (Cypress Lawn)	1893	...	...	...	...	...	...	...	...	...	...	42	111	88	70	54	65	430
Chicago, Ill	1893	...	...	...	...	...	...	...	...	...	...	6	42	66	54	82	130	380
Los Angeles, Cal.	1887	...	...	...	...	7	5	12	17	29	41	37	38	37	37	34	58	352
Detroit, Mich.	1887	...	...	...	...	3	10	14	24	21	33	47	22	31	29	44	51	329
Pittsburg, Pa.	1886	...	...	...	14	9	11	8	9	13	14	13	10	13	14	16	23	167
Baltimore, Md.	1889	...	...	...	...	...	...	3	5	12	16	22	15	11	17	21	14	136
Lancaster, Pa.	1884	...	3	36	14	13	6	1	3	1	3	5	2	1	1	1	2	92
Davenport, Ia.	1891	...	...	...	...	...	...	...	...	6	7	13	8	8	9	23	17	91
Milwaukee, Wis.	1895	...	...	...	...	...	...	...	...	...	...	...	...	...	21	34	30	85
Washington, D. C.	1896	...	...	...	...	...	...	...	...	...	...	...	...	...	...	25	38	63
Pasadena, Cal.	1895	...	...	...	...	...	...	...	...	...	...	...	...	4	14	13	24	55
Washington, Pa.	1876	25	13	1	1	...	...	...	...	...	...	...	2	...	...	...	...	42
St. Paul, Minn.	1897	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	11	13
Fort Wayne, Ind.	1895	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5	1	6
Middletown, Conn. (Asylum)	1897	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Mt. Auburn, Mass. (Cambridge)	1900	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Totals	...	25	16	47	114	127	190	249	372	471	561	674	831	1017	1101	1391	1699	8885

TOTAL YEARLY CREMATIONS IN GREAT BRITAIN.

Crematories.	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	Total.
Glasgow	...	...	...	...	...	...	...	...	...	...	1	10	16	12	39
Liverpool	...	...	...	...	...	...	...	...	...	...	...	2	10	27	39
London (Woking)	8	10	13	28	46	54	99	104	101	125	150	137	173	240	1283
Manchester	...	...	...	...	...	...	...	3	30	47	58	52	51	62	303
Totals	8	10	13	28	46	54	99	107	131	172	209	201	250	341	1664

by Dr. Samuel W. Abbott,[1] contributed by the Commonwealth of Massachusetts to the United States Social Economy Exhibit at the Paris Exposition. During this period, 8,885 cremations occurred.

The first table on page 776, from the same monograph, shows the progress of the movement in the United States. The second table shows the growth of the movement in Great Britain to 1899.

Next to the United States in the number of crematories stands Italy, where, in 1901, 22 were in operation. The movement began in Italy in 1857, but nothing was accomplished until 1897, three years after legal sanction was obtained. Germany had, in 1901, 7 establishments, the first of which was installed at Dresden in 1874; Great Britain had 7, the first of which was established in London in 1885; France had 2, Switzerland had 3, Sweden had 2, and Denmark had 1.

According to Sir Henry Thompson,[2] there were in the United States during 1901, no less than 2,605 incinerations; in Germany, 693; in England, 445; in Paris, 297; in Italy, at 12 of the 22 institutions, 243; in Switzerland, at 2 of the 3 institutions, 144.

In the destruction of the body, the apparatus is so constructed that, while reduction to ashes is complete within three hours, no offensive fumes are given off. Commonly, the body, inclosed in a simple wooden coffin, is placed in the retort, which is then intensely heated by an oil flame, with which air under pressure is mixed by a blower.

[1] The Past and Present Condition of Public Hygiene and State Medicine in the United States, Boston, 1900.

[2] The Lancet, July 5, 1902.

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